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Seasonal Occurrence of Reef-Related Medusae (Cnidaria) in the Western Caribbean Sea

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SEASONAL OCCURRENCE OF REEF-RELATED MEDUSAE (CNIDARIA) IN THE WESTERN CARIBBEAN SEA

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ABSTRACT Seasonal fluctuations in composition and abundance of medusae collected in a reef lagoon of the Mexican Caribbean were analyzed. Plankton samples and hydrological data were taken monthly from January to September 1994 at 2 stations: coastal and near-reef. The highest densities of medusae were recorded in March (17,687 ind/100 m^3) and August (2,433 ind/100 m^3) at the coastal station. Medusae were less abundant at the near-reef station, but diversity indices were higher in comparison to the coastal station. Twenty-five species (24 hydroidomedusae and 1 scyphomedusa) were identified, with *Linuche unguiculata* (Swartz, 1788) and *Eirene lactea* (Mayer, 1900) being the most abundant. *Linuche unguiculata* was the dominant species, accounting for more than 84% of the total numbers of medusae in the coastal station and over 97% in the near-reef station. The co-occurrence of neritic and oceanic species in the reef-associated community of medusae is probably related to circulation patterns and wind regimes. *Dipurena ophiogaster* (Haeckel, 1879) and *Sarsia eximia* (Allman, 1859) were recorded for the first time in the Mexican Caribbean Sea.

INTRODUCTION

Generally, in tropical zones only small seasonal fluctuations in total abundance of zooplankton are common. In many cases, changes in numerical abundance of individual species can be associated with variable hydrographic conditions locally rather than with seasonal changes in production (Lewis and Fish 1969, Sale et al. 1978, Guzmán and Obando 1988). In dynamic ecosystems such as reef lagoons where the reef acts as a hydrodynamic barrier (Ogden and Gladfelter 1983), variations in planktonic communities are influenced by oceanographic factors (i.e., currents, temperature, salinity, substrate, and diel cycles) as well as by their own endogenous rhythm (Lefevre 1985).

The second largest barrier reef in the world is located along the Caribbean coast. This reef runs from Isla Contoy to Belize (Jordán 1993). Only a few studies have been conducted on the reef-related medusan fauna along this shallow barrier. Araneda (unpubl. data) analyzed diel variations of the medusan community in the fore-reef (oceanic) zone and in the reef lagoon in Puerto Morelos from June to December 1991. Suárez-Morales et al. (1999a) studied small-scale space and time variation in the medusan community of the Mahahual reef system. Gasca et al. (2003) described the community structure of the reef-related medusan fauna collected in Banco Chinchorro, a large oceanic atoll found off the southern part of the state of Quintana Roo, Mexico. In Belizean waters, Larson (1982) made a qualitative and quantitative study of medusae at Carrie Bow Cay between January and April 1978.

The present study describes changes in the numerical abundance, composition, and diversity of the reef-related medusae between January and September 1994 in the Puerto Morelos reef lagoon in the Mexican Caribbean Sea. The surveyed area is located at 20°52'N and 86°51'W on the northeastern coast of the Yucatan Peninsula. The oceanographic characteristics of this zone are influenced by the northward flow of the Yucatan Current and by a countercurrent that runs south very close to the continental slope which varys in strength and size throughout the year (Merino 1997). On the Caribbean coast the shelf is very narrow, ranging between 1 and 2 km and widening to the north of Puerto Morelos. The width of the reef lagoon (distance from sea shore to reef barrier) varies between 350 and 1600 m with an mean depth of 3 m and a maximum depth of 8 m (Merino and Otero 1991). The bottom is alternately covered by calcareous sand and large patches of seagrasses dominated by *Thalassia testudinum* (Banks ex König). The water column is highly transparent. Horizontal secchi disk readings as measured by the CARICOMP group in 1992–1993 averaged 15 m—a range of 5 to 20 m. Surface temperature during the same period ranged between 25 and 31 °C with almost constant salinity near 36 psu (Ruiz-Rentería et al. 1998). The tidal regime is mixed semi-diurnal, with a small range of 0.24 m (Instituto de Geofísica 1992).

MATERIALS AND METHODS

Field methods

Zooplankton samples and hydrological data were collected at monthly intervals from January to September 1994 between 18:00 and 19:30 h at 2 stations. Station A is about 20 m off the coast and station B is located near the reef about 800 m from the coast (Figure 1). Station B was not sampled in January and August due to bad weather. A near-surface horizontal haul of ~10 min duration following
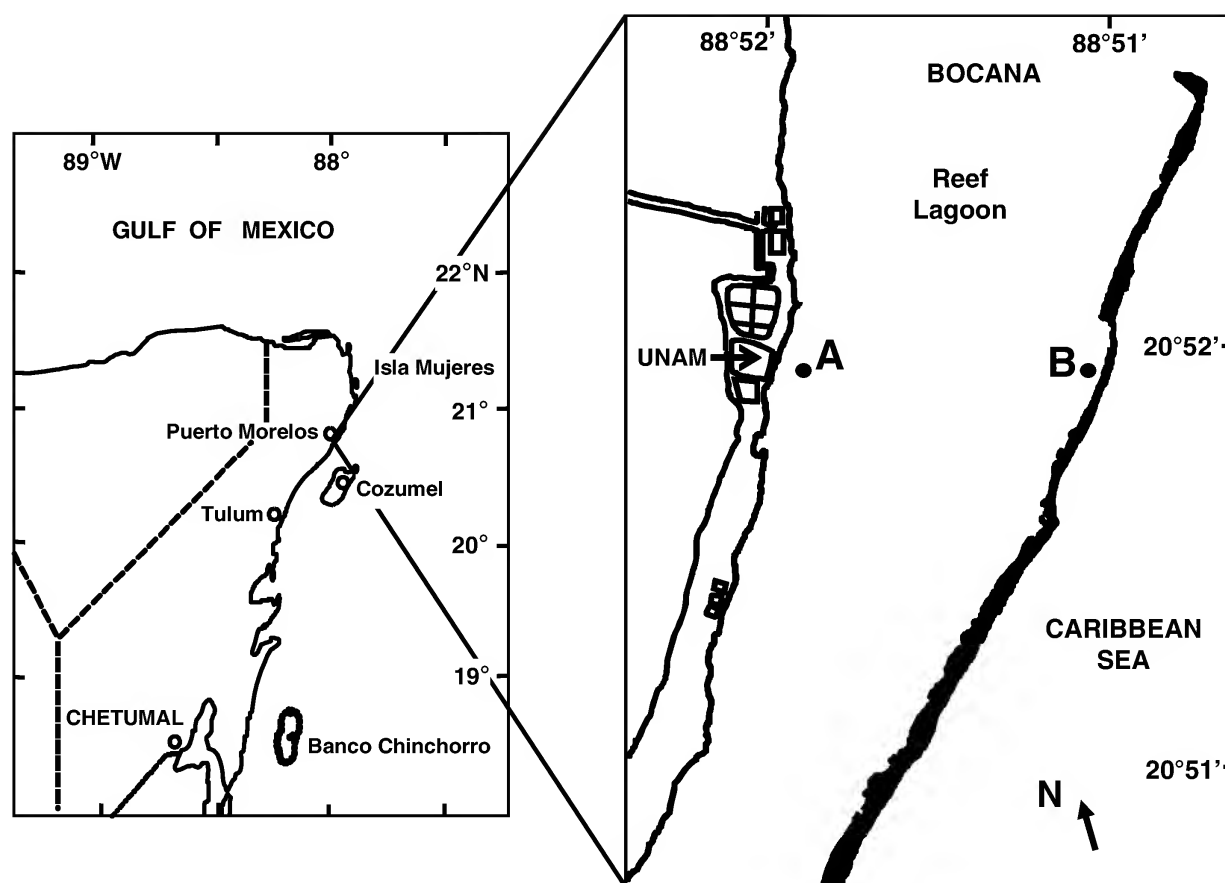
Figure 1. Location of the 2 sampling stations in the Puerto Morelos reef lagoon.

a circular path at 1.5 kn was made at each station with a conical plankton net (40 cm mouth diameter, 1.30 m length and 0.33 mm mesh-size). A digital flow-meter (General Oceanics, USA) was attached to the mouth to estimate the volume of water filtered. Zooplankton samples were fixed in a 4% formaldehyde solution buffered with sodium borate (Smith and Richardson 1979). Temperature was measured in situ with a bucket thermometer and salinity was measured in the laboratory using a Beckman induction salinometer.

Laboratory methods

All medusae were sorted, identified, and counted then the counts were standardized to number of individuals per 100 m^3. Taxonomic references for identifications and nomenclature follow Mayer (1910), Russell (1953), Kramp (1959, 1961), Bouillon (1985), and Bouillon and Boero (2000).

Because data were not distributed normally, a non-parametric paired sample Wilcoxon test (Zar 1974) was applied to evaluate differences in density between the 2 sampled stations. Additionally, a paired t-test (Zar 1974) was applied to log_{10}-transformed data after exclusion of

the dominant species *Linuche unguiculata* (Swartz). Diversity was estimated using the Shannon-Wiener Index (Krebs 1985). The Pearson correlation coefficient (r) was used to infer relationships between species abundance and physical factors.

RESULTS

Surface temperatures during the survey period ranged from 27.2 to 30.9 °C, with minimum values in February and March and maximum values in August. The temperature was similar at the 2 stations, differing by less than 1 °C. Salinity ranged from 35.7 to 36.2 psu, with a minimum in February and September and a maximum in July (Figure 2).

Total density of medusae showed temporal variation throughout the survey period. Two density pulses were obseved at station A. The highest was recorded in March, with 17,687 ind/100 m^3 and was dominated by the scyphomedusa *L. unguiculata*. The second highest density occurred in August with 2,433 ind/100 m^3, with the most abundant species being the hydroidomedusa *Eirene lactea* (Mayer). The lowest density was recorded in January with
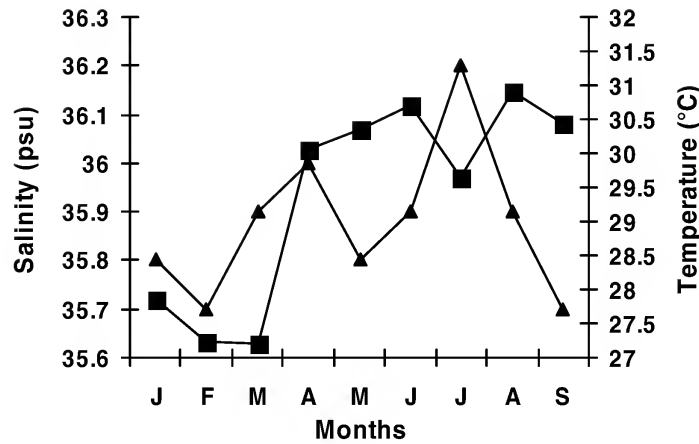
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Figure 2. Monthly variation in the mean surface temperature (°C) and salinity (psu) in the study area during January to September 1994.

5 ind/100 m³. At station B, the highest density was also observed in March with 9,478 ind/100 m³ again dominated by *L. unguiculata*. The lowest density at station B occurred in May with 8 ind/100 m³ (Figure 3). There was no significant difference in the mean density between the 2 sampled stations when *L. unguiculata* was included in the analysis ($z = 1.352$, $P = 0.176$, $n = 7$) or when it was excluded ($t = 0.647$, $P = 0.117$, $n = 7$). There was no significant correlation between water temperature or salinity and the overall density of medusae at either station. Indices for temperature were $r = 0.44$, $P = 0.24$; $r = 0.1$, $P = 0.94$ and for salinity $r = 0.09$, $P = 0.99$; $r = -0.21$, $P = 0.48$.

A total of 25 species (24 hydroidomedusae and 1 scyphomedusa) were recorded in the surveyed area (Tables 1 and 2). *Linuche unguiculata* was by far the most abundant species, accounting for more than 84% of the total population of medusae at the coastal station and over 97% at the near-reef station. *Eirene lactea* was the second most abundant species, representing 14% of the total number of medusae at the coastal station. By contrast, other species such as *Amphinema rugosum* (Mayer), *Dipurena halterata* (Forbes), *Zanclea costata* (Kramp), *Clytia hemisphaerica* (Linné), and *Aglaura hemistoma* Péron and Lesueur were recorded only once during the entire survey. The collection
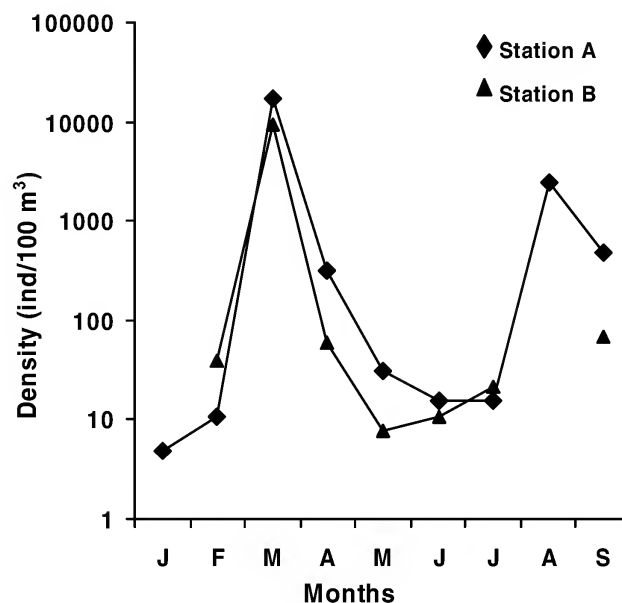

Figure 3. Monthly density (ind/100 m³) of medusae recorded at 2 sampling locations during January to September 1994.

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TABLE 1

Density (ind/100 m³), relative abundance (RA), and relative frequency (RF) of the species of medusae collected monthly at station A in the Puerto Morelos reef lagoon in 1994. *First record for the Mexican Caribbean Sea.

SPECIES	J	F	M	A	M	J	J	A	S	TOTAL	RA	RF
Hydractinia carnea (M. Sars, 1846)					1.6					1.6	0.0	11.1
Hydractinia minuta (Mayer, 1900)				14.7	6.6					21.2	0.1	22.2
Amphinema dinema (Péron and Lesueur, 1809)								1.5		1.5	0.0	11.1
Dipurena ophiogaster Haeckel, 1879				91.6						91.6	0.4	11.1
Sarsia angulata (Mayer, 1900)	1.6		6.3	12.8	1.6			1.5	3.1	25.4	0.1	55.5
Sarsia eximia (Allman, 1859)	1.6	3.1	6.3	137.4	8.2	1.7		3.09	3.1	164.5	0.8	88.8
Sarsia prolifera Forbes, 1848		1.6		5.5						8.6	0.0	33.3
Vannuccia forbesii (Mayer, 1894)					1.6					1.6	0.0	11.1
Euphysa sp. Bouillon, 1974		1.6								1.6	0.0	11.1
Eirene lactea (Mayer, 1900)				29.3	3.3		7.8	2422.2	463.1	2925.6	13.9	55.5
Eucheilota paradoxica Mayer, 1900				3.7	3.3					6.9	0.0	22.2
Clytia discoida (Mayer, 1900)				3.7				1.5	15.5	20.7	0.1	33.3
Clytia folleata (McCrady, 1859)	1.6	1.6		1.8	1.6					6.6	0.0	44.4
Clytia hemisphaerica (Linné, 1767)						8.5				8.5	0.0	11.1
Cubaia aphrodite Mayer, 1894		1.6		11.0	3.3	1.7		1.5		20.6	0.1	66.6
Valentinia gabriellae (Mendes, 1948)									1.6	1.6	0.0	11.1
Liriope tetraphylla (Chamisso and Eysenhardt, 1821)							3.1			3.1	0.0	11.1
Aglaura hemistoma Péron and Lesueur, 1810							1.6			1.6	0.0	11.1
Linuche unguiculata (Swartz, 1788)		1.6	17672.9			1.7	1.6	1.5	1.6	17686.3	84.2	77.7
TOTAL	**4.8**	**10.9**	**17687.1**	**316.9**	**31.1**	**15.3**	**15.5**	**2433.0**	**487.9**	**21002.6**	**100.0**	

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TABLE 2

Density (ind/100 m^3), relative abundance (RA), and relative frequency (RF) of the species of medusae collected monthly at station B in the Puerto Morelos reef lagoon in 1994. *First record for the Mexican Caribbean Sea.

Species	F	M	A	M	J	J	S	TOTAL	RA	RF
Hydractinia carnea (M.Sars, 1846)			3.4				4.7	8.1	0.1	28.6
Hydractinia minuta (Mayer, 1900)			8.6			1.6		10.1	0.1	28.6
Amphinema dinema (Péron and Lesueur, 1809)		1.4			1.5	1.6	1.6	6.0	0.1	57.1
Amphinema rugosum (Mayer, 1900)						1.6		1.6	0.0	14.3
Dipurena halterata (Forbes, 1846)							1.6	1.6	0.0	14.3
*Dipurena ophiogaster Haeckel, 1879			3.4					3.4	0.0	14.3
Sarsia angulata (Mayer, 1900)	1.5	5.7	1.7	4.6			6.2	19.8	0.2	71.4
*Sarsia eximia (Allman, 1859)	6.0	2.8	15.4				12.4	36.7	0.4	57.1
Sarsia prolifera Forbes, 1848			1.7					1.7	0.0	14.3
Vannuccia forbesii (Mayer, 1894)	1.5							1.5	0.0	14.3
Zanclea costata (Kramp, 1959)	3.0							3.0	0.0	14.3
Pachycordyle sp. Weismann, 1883							3.1	3.1	0.0	14.3
Eirene lactea (Mayer, 1900)			5.1				17.1	22.2	0.2	28.6
Laodicea undulata (Forbes and Goodsir, 1851)						1.6	3.1	4.7	0.0	28.6
Eucheilota paradoxica Mayer, 1900		1.4	6.8				15.5	23.8	0.2	42.8
Clytia discoida (Mayer, 1900)		7.1	5.1	1.5	1.5		4.7	16.0	0.2	71.4
Clytia folleata (McCrady, 1859)	1.5			1.5	3.0			8.1	0.1	28.6
Obelia sp. Péron and Lesueur, 1810		1.4	6.8					8.3	0.1	28.6
Vallentinia gabriellae (Mendes, 1948)					1.5			1.5	0.0	14.3
Liriope tetraphylla (Chamisso and Eysenhardt, 1821)		1.4				10.9		12.3	0.1	28.6
Linuche unguiculata (Swartz, 1788)	18.1	9456.5			1.5	3.1		9479.0	97.9	57.1
TOTAL	39.1	9477.9	58.2	7.7	10.5	21.8	69.9	9685.1	100.0	

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of *Dipurena ophiogaster* Haeckel and *Sarsia eximia* (Allman) in the area represent new Mexican Caribbean records for these hydroidomedusae.

Fifteen species were common to both the coastal and near-reef stations. Four species (*Euphysa* sp., *C. hemisphaerica*, *Cubaia aphrodite* Mayer, and *A. hemistoma*) were restricted to the coastal station and 6 species (*A. rugosum*, *D. halterata*, *Z. costata*, *Pachycordyle* sp., *Laodicea undulata* (Forbes and Goodsir), and *Obelia* sp.) occurred only at the near-reef station. Most of the species recorded are neritic forms, with only 2 oceanic species collected—*A. hemistoma* and *Liriope tetraphylla* (Chamisso and Eysenhardt).

Species richness was highest at the near-reef station where 21 of the 25 species were collected. The lowest number of species (2) was recorded in May and the highest number of species (10) was recorded in April and September. Nineteen species were collected at the coastal station with the lowest number (3) being observed in January and the highest number (11) in April (Table 3). In the near-reef station, the values of the Shannon-Wiener diversity were high, varying from 0.03 to 3.04 (March and April, respectively). The coastal station had lower diversity values of 0.01 to 2.90 in March and May, respectively.

DISCUSSION

Density of medusae recorded in this study ranged from a minimum of 5 to a maximum of 17,687 ind/100 m^3. Araneda (unpubl. data), in a study of medusan fauna in the Puerto Morelos reef lagoon, found densities ranging from 76 to 28,000 ind/100 m^3. The densities recorded at Mahahual reef by Suárez-Morales et al. (1999a) ranged between 1 and 195 ind/100 m^3, whereas Gasca et al. (2003), studying the medusae at Banco Chinchorro, reported mean densities ranging between 12 and 182 ind/100 m^3. In the waters from Carrie Bow Cay, Belize, Larson (1982) reported mean densities of medusae ranging between 1 and

TABLE 3

Species of medusae collected monthly at stations A and B in the Puerto Morelos reef lagoon in 1994.

(MONTH/STATION)	J	F		M		A		M		J		J		A	S	
SPECIES	A	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B
Hydractinia carnea						+	+	+								+
Hydractinia minuta					+	+	+	+					+			+
Amphinema dinema													+	+		+
Amphinema rugosum													+			
Dipurena halterata																+
Dipurena ophiogaster						+	+									
Sarsia angulata			+	+	+	+	+	+	+					+	+	+
Sarsia eximia	+	+	+	+	+	+	+	+		+				+	+	+
Sarsia prolifera	+	+				+	+									
Vannuccia forbesi			+						+							
Euphysa sp.		+														
Zanclea costata			+													
Pachycordyle sp.																+
Eirene lactea						+	+	+			+	+		+	+	+
Laodicea undulata													+			+
Eucheilota paradoxica				+	+	+		+								+
Clytia discoida			+		+	+	+	+			+			+	+	+
Clytia folleata	+					+	+	+			+					
Clytia hemisphaerica										+						
Obelia sp.					+		+									
Cubaia aphrodite		+				+		+		+				+	+	
Vallentinia gabriellae											+					
Liriope tetraphylla			+		+							+	+			
Aglaura hemistoma												+				
Linuche unguiculata		+	+	+	+	+				+	+	+	+	+	+	
TOTAL	**3**	**5**	**7**	**4**	**8**	**11**	**10**	**9**	**2**	**4**	**5**	**4**	**6**	**7**	**6**	**10**

831 ind/100 m^3. The differences in density recorded in these studies may be the result of hydrographic and ecological features of each of the sampled areas. Differences in density may also reflect local high aggregations of particular species and may be linked to different sampling efforts over different temporal and spatial scales.

The overall density of the medusan fauna showed seasonal variability throughout the studied period and were dominated by *L. unguiculata*. This small coronate scyphomedusa occurs in dense aggregations during the spring. Recently, the whole life cycle of *L. unguiculata* under natural and experimental conditions, has been studied in relation to outbreaks of "seabather's eruption" in the Mexican Caribbean (Segura-Puertas et al. 2001). In late January the scyphistomae (polyps) release huge numbers of ephyrae which grow and mature into adults between March and May. In May and early June, the planktonic planulae of the next generation appear in abundance. The phases of the life cycle can be observed sequentially, overlapping from late winter until late spring (Segura-Puertas et al. 2001). The seasonal occurrence of this species seems to be a distinctive and dominant feature of the neritic and near-ocean environments along the western Caribbean Sea (Larson 1982, Suárez-Morales et al. 1999b) and is influenced by an increase in the water temperature (Segura, in prep.). Larson (1992), studying aggregations of *L. unguiculata* along the Belizean reef barrier, found that physical factors, especially Langmuir circulation and the circular swimming behavior of the medusae, are the primary mechanisms responsible for such aggregations. According to this author, swarms of this scyphomedusa probably improve fertilization by minimizing sperm dilution. Larson (1992) also found that wind patterns (direction and speed) play an important role in the variation of both the shape and the density of the aggregations. The highest numbers of *L. unguiculata* recorded in the survey area may be partially determined by the wind regime. When the east and southeast trade winds are dominant, dense aggregations of this species accumulate in the reef lagoon and along the shore line. In contrast, when northerlies are dominant, the aggregations are observed in the open sea.

Eirene lactea was the second most dense species of hydroidomedusa recorded. The highest density value was observed in August. Similar results were obtained by Araneda (unpubl. data), who recorded *E. lactea* as a dominant species with the highest density in September and October. Differences in time suggest an interannual variability between the pulses of maximum density of this neritic species. In contrast, the communities of medusae recorded off Mahahual, Banco Chinchorro, and Carrie Bow Cay, Belize were numerically dominated by 2 ocean-ic species, *L. tetraphylla* and *A. hemistoma* (Larson 1982, Suárez-Morales et al. 1999a, Gasca et al. 2003). The difference in composition indicates distinct community structures and may be due to local hydrology interactions with topography.

No significant correlations between temperature or salinity and density of medusae were found. These results suggest that the community of medusae may be controlled by other factors such as hydrographic conditions, food availability, and in the case of hydroidomedusae, the complexity of their life cycles.

The medusan fauna is particularly diverse in reef environments. The number of species recorded in the present study was 25. This is lower than that recorded in Carrie Bow Cay, Belize (71 species) by Larson (1982) but higher than those found in Mahahual (17 species) by Suárez-Morales et al. (1999a) and in Banco Chinchorro (16 species) by Gasca et al. (2003). The differences in diversity observed among the locations may result partially from the different sampling efforts and may also reflect the heterogeneity of methods used in the collection. For example, in the study by Larson (1982) medusae were captured using a plankton net, by beach seine, night light, dip net, and while diving.

The Shannon-Wiener species diversity indices obtained in our study can be considered as high, especially at the near-reef station (3.04). This increase the local species richness clearly reveals the influence of oceanic water in the reef lagoon system. The occurrence of *L. tetraphylla* and *A. hemistoma*, although in low numbers, can be considered an indication of oceanic influence. This effect has been observed by other authors in adjacent reef areas (Larson 1982, Suárez-Morales et al. 1999a, Gasca et al. 2003) and may be a consequence of the narrowness of the continental shelf in the region.

Only 50% of the species recorded in this work have been reported previously from the Campeche Bank and part of the Mexican Caribbean (Segura-Puertas 1992, Segura-Puertas and Ordóñez-López 1994), whereas 61% are known from coastal environments along the Mexican Caribbean (Zamponi et al. 1990, Suárez-Morales et al. 1997, 1999a, b). Only 2 species collected in the surveyed area, *D. ophiogaster* and *S. eximia*, have not been recorded previously in the Mexican Caribbean Sea.

Dipurena ophiogaster is a small hydroidomedusa that has been recorded on the south coast of Britain (Haeckel 1879), in the Mediterranean (Chun 1896), in Ceylon (Mayer 1910), in the south of Japan (Yamazi 1958), in the Bay of Valencia, Ireland (Russell 1938), in the Palau Islands, Central Pacific (Uchida 1947), and in the Gulf of Mexico (Phillips 1972).

Sarsia eximia is a small neritic species. The distribution of this species includes northwestern Europe, the western region of the Mediterranean, the west coast of North America (Kramp 1958), the Adriatic Sea (Mayer 1910), the British Isles (Russell 1953) and the western tropical Pacific, Peru, and Chile (Vannucci 1957). The collection of *D. ophiogaster* and *S. eximia* in the Mexican Caribbean extends their geographical distribution limit to the western tropical Atlantic.

In summary, the surveyed area contains a relatively homogeneous medusan fauna characterized by the co-occurrence of neritic and oceanic forms regulated by the local hydrographic conditions. This community shows seasonal changes in abundance and composition with 2 important pulses—one in spring dominated by the scyphozoa *L. unguiculata* and the second during late summer characterized by the hydroidomedusa *E. lactea*. Most of the species collected have previously been recorded from the region (Segura-Puertas 1992, Segura-Puertas and Ordópez-López 1994, Suárez-Morales et al. 1999a), but there are 2 new records for the Mexican Caribbean, *D. ophiogaster* and *S. eximia*. Although this survey focused on the medusa stage only, it is important to emphasize the relevance of studying both planktonic (medusa) and benthic (polyp) phases of their life cycle to understand the dynamics of this important group.

ACKNOWLEDGMENTS

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Formation of a Stress-Induced Check Mark on the Otoliths of Juvenile Fishes: Implications for Mesocosm Studies

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FORMATION OF A STRESS-INDUCED CHECK MARK ON THE OTOLITHS OF JUVENILE FISHES: IMPLICATIONS FOR MESOCOSM STUDIES

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ABSTRACT Daily otolith increment widths of spot *Leiostomus xanthurus* and spotted seatrout *Cynoscion nebulosus* were examined experimentally in field mesocosms for 5 to 7 days in various habitat types. Daily otolith increments were used as a surrogate for daily somatic growth so that growth prior to capture and handling could be examined. For both species, possible effects of habitat types were confounded by an overall decrease in daily increment widths during the experimental period when compared to increment widths prior to capture. Several spotted seatrout inadvertently captured during mesocosm deployment provided a means for assessing if there was a significant mesocosm effect or if capture and handling may have caused the decreased increment widths. These "volunteers" were distinguishable from experimental fish by the occurrence of a check mark on the otoliths of the experimental fish. Because experimental increment widths of "volunteers" were not different from pre-experimental widths, handling rather than caging effects appeared responsible for reduced increment widths. While there appeared to be no "mesocosm" effect, handling stress potentially affected growth longer than the 24 h acclimation period we anticipated. Short-term effects of capture and handling of wild fish for mesocosm use should be explored and accounted for in future studies.

INTRODUCTION

Enclosures or experimental mesocosms have been used in aquatic research for a variety of investigations including growth (Sogard 1992, Keller and Klein-MacPhee 2000), survival (Cowan et al. 1992, Stunz and Minello 2001), predation (Elliot and Leggett 1996, Kim and Devries 2001), and ecological risk analysis (Boyle and Fairchild 1997). Mesocosms provide an experimental method for confining test subjects in areas of known environmental characteristics (e.g., substrate type, emergent vegetation) while allowing other abiotic factors (e.g., salinity, temperature) to fluctuate naturally (Cline et al. 1994, Breitburg et al. 1997). As such, mesocosms may be an excellent tool for assessing the relative value of various habitat types to growth and survival of juvenile fishes. However, interpretations of results from mesocosm studies have been criticized on the basis of scale and artificiality (Petersen et al. 1999) and failure to recognize that experimental manipulations or natural phenomena may unequally interact with treatments (Peterson and Black 1994).

To address questions regarding the value of shallow-water habitat types for early growth in juvenile estuarine fishes, we conducted experiments using mesocosms and 2 species of estuarine fish. The main objective of this study was to use growth, as measured by daily otolith increment widths, to assess the relative value of various shallow-water habitat types common in the northern Gulf of Mexico (GOM). For a variety of reasons, we were unable to meet our objectives and post-experimental analyses could not overcome the problems encountered during our investigations. However, unexpected results from these experiments have allowed inferences on the use and effectiveness of mesocosms for in situ experiments such as those performed in this study. The objectives of this paper were to identify the problems encountered as part of this study, suggest means for improving similar designs, and provide evidence on the potential effects capture and handling may have on subsequent short-term growth of juvenile fishes.

MATERIALS AND METHODS

Spot *Leiostomus xanthurus* and spotted seatrout *Cynoscion nebulosus* are common residents in South Atlantic and GOM estuarine systems (Weinstein 1979, Baltz et al. 1993). In northern GOM waters, spot typically recruit to nursery grounds in the early spring (February–March) and seatrout recruit throughout the summer (June–August; Baltz et al. 1993). Their abundance and temporal distribution make them excellent candidates for serial studies examining growth over common habitat types found in the northern GOM. The in situ studies took place in a *Spartina*-dominated saltmarsh, near Fourchon, Louisiana, in March and August, 1992.

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On the day before each experiment began, 20 cylindrical mesocosms were set from a boat to minimize disturbance and to allow any disturbed substrate to settle. Mesocosms were constructed from colorless polycarbonate sheets, measuring 1.25 m in height with a basal area of 0.44 m². Three rows of 10 cm diameter openings covered by screens of 5 x 3.5 mm mesh encircled each mesocosm. These mesh openings allowed water and plankton to pass through while effectively retaining experimental fish. A remote water-quality probe, centrally located between mesocosms, monitored temperature (°C), dissolved oxygen (mg/l), salinity (psu), and relative tidal height (cm) during the experimental period.

On the day prior to each experiment, fish were captured by seine in an area adjacent to the experimental site. Individuals were not measured at the time of capture in an attempt to reduce handling stress. Additionally, salinity and temperature were reduced slightly (1–2 psu and 1–2 °C) in initial holding water to further alleviate stress (Kelsch and Shields 1996). Fish were transferred within the hour to aquaria containing water of ambient temperature and salinity and held for about 12 h to ensure that only healthy fish were used. At the beginning of each experiment, 2 individual fish were randomly selected and placed into each mesocosm (i.e., 4.5 fish/m²). Typical mean densities for occupied habitats in Louisiana for juvenile spot are 10.8/m² (maximum density of 40/m²) and 2.2/m² (maximum density of 10/m²) for juvenile spotted seatrout (Baltz et al. 1993).

The spot experiment examined 4 habitat types: mud, sand, mud with emergent *Spartina* stems (mud/stem), and sand with emergent *Spartina* stems (sand/stem). The spotted seatrout experiment compared only sand and sand/stem treatments, but did so using 2 different mesh types (the standard mesh of the spot experiment and fine mesh designed to exclude mysid shrimp that were attracted to the chamber structure; see Reinert 1993). The spot experiment lasted the planned 7 days, but the seatrout experiment only lasted 5 days, due to approaching inclement weather. At the end of each experimental period, fish were retrieved by dip net and the enclosed water was pumped through a 333 μm mesh plankton net to ensure that all remaining fish were recovered. Immediately following retrieval, standard length (SL) in mm was recorded and sagittal otoliths were removed from each fish.

In the lab, otoliths were embedded in an epoxy resin and sectioned in the transverse plane to produce a thin section around the core of the otolith (Haake et al. 1982). Otoliths were sanded and polished until daily increments were visible. At this point, if an otolith was not suitable for reading, it was etched with 0.1 N HCl to enhance readability (Secor et al. 1991). All increment measurements were accomplished with a calibrated image processing system on a microcomputer. Increments were measured along the same radius, immediately adjacent to the sulcus groove on each otolith. Pre-experimental increment widths were measured for the 5 daily increments immediately prior to the day of capture. The first experimental increment (i.e., day one of the experiment) and last daily increment (i.e., day 5 or day 7 for seatrout and spot, respectively) were omitted as they represented an acclimation day and an incomplete daily increment. Because otolith increment widths were analyzed in 2 time frames, a split-plot statistical analysis based on time (in days) was used to compare treatments and pre-experimental and experimental increment widths (Maceina et al. 1994).

RESULTS

Spot

Of the 40 spot initially placed into mesocosms, 24 were recovered at the end of the experiment. Mean SL (mm) for experimental fish was $41.1 \pm 4.80\ s$. At least one spot was retrieved from each of the 5 mud mesocosms, from 4 of the sand mesocosms, and from 4 of the sand/stem mesocosms. Two mud/stem mesocosms drained completely during the experiment and fish were not retrieved. At least one fish was retrieved from each of the 3 remaining mud/stem mesocosms.

In the split-plot ANOVA, we were unable to detect a significant influence on increment width attributable to substrate type ($P = 0.975$), the presence or absence of emergent *Spartina* stems ($P = 0.379$), or their interaction ($P = 0.288$). Pre-experimental increment widths ($n = 5$ days prior to capture) were pooled to determine a pre-experimental increment growth rate. Comparison of mean pre-experimental increment width (i.e., prior to capture) and experimental increment widths (days 2–6) was highly significantly different ($P \leq 0.0001$). Mean pre-experimental increment width for all spot, was $3.10 \pm 0.08\ s_{\bar{x}}$ μm/d (Figure 1). Because no treatment differences were evident, daily increment widths were pooled across treatments for the experimental period. Individual mean daily experimental increment widths ranged from 1.94 to 2.58 μm with an overall group mean of $2.07 \pm 0.05\ s_{\bar{x}}$ μm/d (Figure 1). Each otolith displayed a check mark formed on the day of capture, presumably due to the stress of capture and handling.
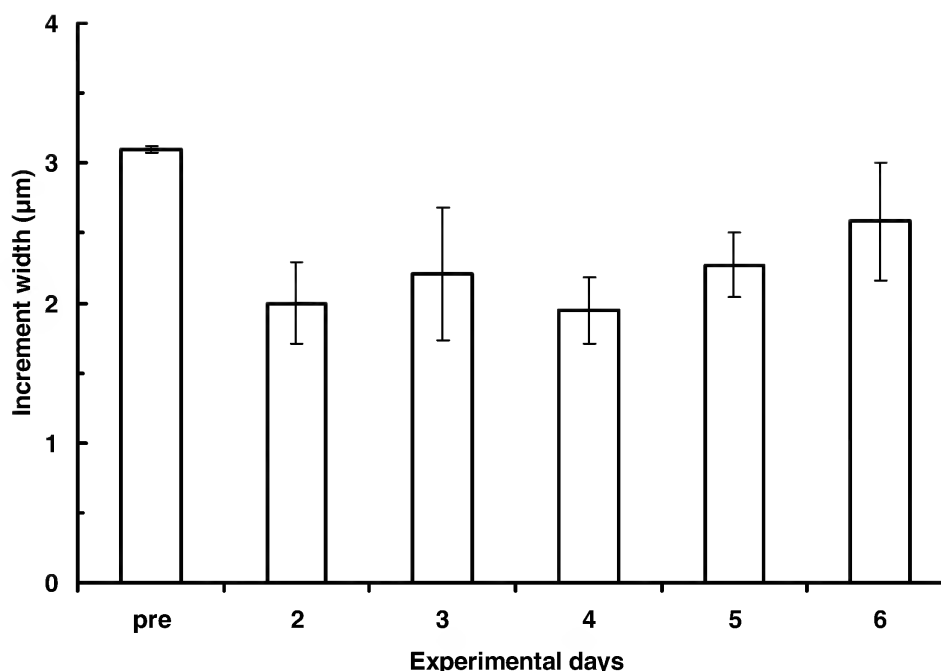
Figure 1. Mean daily increment widths from spot *Leiostomus xanthurus* otoliths for 5 days prior to capture (pooled and labeled as "pre") and during experimental days 2–6, while confined to mesocosms near Fourchon, Louisiana, March 1992. Experimental days 1 and 7 were omitted as acclimation and incomplete days, respectively. Increment widths during experimental days are pooled across treatments. Error bars are 95% confidence intervals.

Spotted Seatrout

At the end of the spotted seatrout experiment, 15 more seatrout were retrieved than were initially placed into the ten mesocosms containing emergent *Spartina* stems. As all of the screened portholes were intact, these extra fish apparently were trapped during initial deployment of the mesocosms. Experimental fish were distinguishable by the presence of a stress-induced check mark similar to those found on the spot otoliths. The "volunteer" seatrout lacked a similar check (Figure 2). Overall, 52 spotted seatrout were retrieved. Three experimental fish were missing (from treatments over bare sand). Mean SL (mm) for experimental fish ($n = 37$) was 26.6 ± 3.50 s; mean "volunteer" fish ($n = 15$) SL was 22.2 ± 4.62 s; and overall, mean SL was 25.5 ± 4.30 s.

For experimental fish, the split-plot analysis did not detect any differences in increment width due to the presence or absence of emergent *Spartina* stems ($P = 0.629$), mesh type ($P = 0.834$), or their interaction ($P = 0.115$). Mean daily increment widths were significantly greater during the period prior to capture than during the experiment ($P = 0.005$, Figure 3). Mean increment width pooled across the 5 days prior to capture was 10.37 μm ± 0.21 $s_{\bar{x}}$, and mean increment widths for the 3 experimental days averaged 9.29 μm ± 0.35 $s_{\bar{x}}$.

We were unable to detect significant differences in overall experimental increment widths (days 2–4) between the 2 groups of seatrout (handled and "volunteer"; $P = 0.415$). However, increment width comparison of "volunteer" and experimental fish across time was significantly different ($P = 0.038$), indicating that experimental fish and "volunteer" fish responded differently during the experiment. Increment widths of the experimental fish were lower during the experimental period when compared to the pre-experimental period; however, "volunteer" fish did not show a detectable difference in increment widths between periods (Figure 3).

DISCUSSION

Results from experiments investigating effects of various habitat variables on individual growth of juvenile spot and spotted seatrout were confounded by reduced otolith increment widths during the experimental period. Additionally, we initially relied on the untested assumption that otolith increment width was proportional to daily somatic growth. Although otolith increment widths are usually related to somatic growth and may be used as a measure of recent daily growth (Methot Jr. 1981, Wilson and Larkin 1982, Burke et al. 1993), decoupling of the otolith growth-somatic growth relationship can occur (usu-
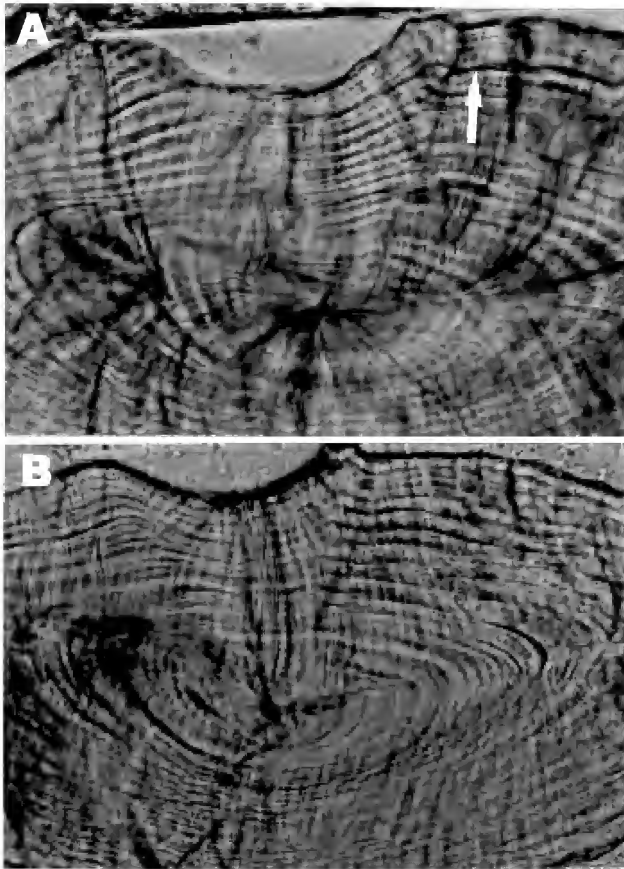
Figure 2. A) Evidence of a stress induced check mark (↗) on the otolith of an experimentally manipulated spotted seatrout. The check mark occurs on the day of capture. B) "Volunteer"seatrout (i.e., those individuals inadvertently captured during deployment of experimental mesocosms and not handled at all) lacked a similar check mark. Experiments were conducted near Fourchon, Louisiana, in August, 1992.

1977), or handling (Paragamian et al. 1992, Zhang et al. 1995). All fishes that were captured and handled in our study displayed check marks on the day of capture, indicating they had experienced significant physiological stress at that time. Deliberate check-mark induction has been achieved through fluctuations in water temperature (Volk et al. 1994). Although not our intended purpose, we did expose experimental fish to lower water temperatures, which may have contributed to check formation.

Increment widths of experimental fish in both studies decreased immediately following capture and placement in the mesocosms. Short-term periods of stress cause a variety of physiological responses in fishes, one of which is impaired growth (Wedemeyer and McLeay 1981). If increment widths are indicative of (if not always directly related to) somatic growth or stress level, handling stress additionally appeared to manifest itself through reduced daily increment widths. "Volunteer" fish did not have a check mark on their otoliths nor did they experience reduced otolith growth during the experimental period.

Overall, the intended objectives of the study could not be met, primarily because of the design of the experiment (i.e., insufficient duration) and reliance on an untested assumption (i.e., no uncoupling of the linear relationship between somatic and otolith growth under stress). However, the inadvertent inclusion of "volunteer" spotted seatrout in the mesocosms provided a unique opportunity to evaluate the use of wild animals in in situ experimentation. The lack of a stress-induced check mark and no change in increment widths during the experimental period of the "volunteer" seatrout demonstrated that, in this case, there was no detectable mesocosm artifact affecting daily otolith increment widths, and thus, mesocosms may be an effective tools for such studies. However, fish that were handled demonstrated a check mark as well as an immediate reduction in otolith increment widths. Even though we tried to reduce handling stress by not measuring the fish ahead of time and attempting to ameliorate the stress response through reductions in salinity and water temperature, experimental fish were negatively impacted by the experience. A longer acclimation period might have allowed the resumption of normal otolith growth (and presumably somatic growth as well). In salmonids, stabilization of increment widths may take as long as 15–21 d depending on experimental conditions (Neilson and Geen 1984, Molony and Choat 1990). Paperno et al. (1997) examined another sciaenid, juvenile weakfish *Cynoscion regalis* and found that increment widths stabilized within a week of experimental manipulation. Additionally, an independent assessment of increment width formation in free-ranging fishes at the conclusion of in situ experiments

ally under stressful conditions), limiting the reliability of daily increment widths to accurately reflect recent patterns in daily growth (Secor et al. 1989, Mugiya and Tanaka 1992). Because we did not measure fish length prior to experimentation (in an attempt to reduce handling stress), this assumption remains untested and may limit conclusions drawn from the results regarding growth responses to habitat variables. However, the accidental inclusion of "volunteer" seatrout during deployment of the experimental mesocosms may yield inferences to future mesocosm studies examining growth, survival, competition, or other in situ biological investigations of fishes.

Check marks on otoliths are formed when normal calcium deposition has been disrupted, usually in association with periods of stress. The stress may be due to the onset of sexual maturity (Campana and Neilson 1985), degraded environmental quality (Kalish 1992), migration (Kawakami et al. 1998), metamorphosis (Bailey et al.
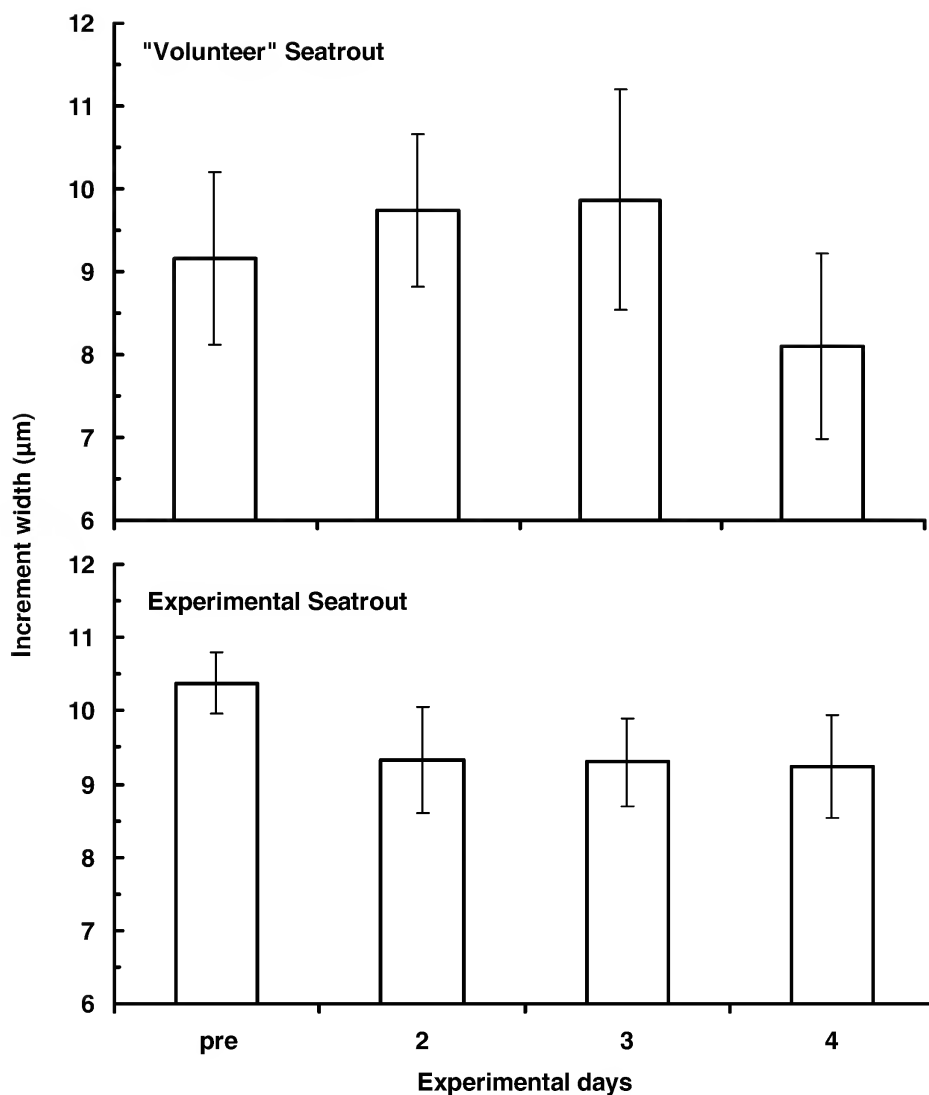
Figure 3. Mean daily increment widths from spotted seatrout *Cynoscion nebulosus* otoliths for 5 days prior to the experimental period (pooled and labeled as "pre") and during experimental days 2–4, while confined to mesocosms near Fourchon, Louisiana August 1992. Experimental days 1 and 5 were omitted as acclimation and incomplete days, respectively. Increment widths during experimental days are pooled across treatments. The top graph shows increment widths of "volunteer" seatrout, and the bottom graph shows increment widths of seatrout that were handled prior to placement into the mesocosms. Error bars are 95% confidence intervals.

(covering the experimental period) would have provided a separate means of verifying growth rates in the wild as compared to those determined during our experiments (Kellison et al. 2003). With these additional procedures and precautions, the use of mesocosms to identify the relative value of estuarine habitat types can be a valuable tool in the study of the early life history of juvenile fishes.

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The First Larval Stage of *Microprosthema semilaeve* (von Martens, 1872) (Crustacea: Decapoda: Stenopodidea) Obtained in the Laboratory

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THE FIRST LARVAL STAGE OF *MICROPROSTHEMA SEMILAEVE* (VON MARTENS, 1872) (CRUSTACEA: DECAPODA: STENOPODIDEA) OBTAINED IN THE LABORATORY

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ABSTRACT The first larval stage of *Microprosthema semilaeve* (von Martens, 1872) is described from ovigerous females collected off Sombrero Key, Florida Keys, USA, and Guana Island, British Virgin Islands, Caribbean. The larvae are characterized by a broad, triangular telson bearing posterolateral spines and an "anomuran seta," a first maxilliped that differs markedly from the very similar (to each other) second and third maxillipeds, and the presence of the first pereiopod as a swimming appendage upon hatching, as is apparently true of all stenopodidean first stage larvae. Characters of the larvae are compared to those described from the Indian Ocean by Raje and Ranade (1978) and mistakenly attributed to this same species, and to those of stenopodidean larvae described by Lebour (1941) from Bermuda plankton. Problems in identifying adult specimens of *Microprosthema* from the Caribbean are discussed.

INTRODUCTION

The decapod crustacean infraorder Stenopodidea comprises 2 families and 9 genera (see Holthuis1993) of small, lobster-like shrimp, many of which are highly colorful. The affinities of stenopodideans to other groups of decapod crustaceans has been an ongoing source of controversy and interest (e.g., see Abele 1991, Martin and Davis 2001). Despite the uncertainty that has always surrounded the relationships of stenopodideans to other decapods, and despite the recognized value of larval stages in taxonomy and phylogeny of decapods (e.g., see Rice 1980, 1983), there are surprisingly few reports of larval stages of any stenopodideans. Most of the descriptions of stenopodidean larvae are from plankton samples with authors suggesting possible species attribution based on adult zoogeographical distributions (Cano 1892, Gurney 1924, 1936, Gurney and Lebour 1941, Kurian 1956, Bourdillon-Casanova 1960, Williamson 1970, 1976, Seridji 1985, 1990). For example, Lebour (1941) (in Lebour and Gurney 1941) described some stenopodidean larvae from Bermuda plankton and was able, with some uncertainty, to assign most of them to genus level. To our knowledge, the only publications in which stenopodidean larvae have been described in any detail from eggs hatched in the laboratory are the works of Brooks and Herrick (1891) on *Stenopus hispidus* and a more recent paper by Raje and Ranade (1978), who described the larval stages of a species of *Microprosthema* from the Indian Ocean. Raje and Ranade (1978) attributed those larvae to the species *M. semilaeve* (Von Martens, 1872); however, the species could not have been *M. semilaeve*, because that species is restricted to the Caribbean and western Atlantic. Thus, Raje and Ranade described larvae of an undescribed

species of *Microprosthema* that one of us (JWG) is describing (see also Goy 1987).

Microprosthema semilaeve is a commonly encountered associate of reefs and rocky areas. The species has been reported throughout the Caribbean and western Atlantic and was thought common enough by Williams et al. (1989) to be assigned the common name "crimson coral shrimp." Below, we provide the first description of the larvae of *M. semilaeve* (von Martens) obtained in the laboratory.

MATERIALS AND METHODS

This study was prompted by the discovery of several small stenopodidean shrimps collected during a survey of the cryptic marine invertebrates of Guana Island, British Virgin Islands (BVI), led by T.L. Zimmerman and J.W. Martin and funded by grants from the US National Science Foundation and the Falconwood Corporation. Although various collecting methods were employed during that survey, the single ovigerous female *M. semilaeve* from which larvae were reared was collected by hand on 18 July 2000 from BVI Station 82, Guana Island, BVI, just off North Beach, central to northeast end, in shallow water (< 1 m), from rock and coral rubble. Collectors were T. Zimmerman, J. Martin, T. Haney, and R. Ware. The ovigerous female was photographed and assigned the photographic voucher number Vc1105; she and all of the first stage larvae (except those dissected and destroyed in the process of describing them) have been deposited in the Natural History Museum of Los Angeles County and assigned catalog number LACM CR 2000-029.1. The live ovigerous female was maintained in seawater about 2 days, with larvae hatching on July 19, one day after capture of

the female. Larvae and the spent parental female were preserved in 70% ethanol. Illustrations of the larvae were made using a Wild M5 stereoscope, a Wild M5 APO stereoscope, or a Nikon Labophot compound microscope, all equipped with drawing tubes. Earlier, another ovigerous female of *M. semilaeve* was collected by Tim Green off Sombrero Key, Florida Keys, USA, at a depth of 5 m in coral rubble on 24 June, 1989. This specimen was brought to one of us (JWG) on 26 June, 1989. From this female, 43 eggs hatched in a prezoeal stage in the laboratory, but only 2 of these prezoeae subsequently transitioned into first zoeae.

Other Caribbean material (adults only) was examined during a visit (JWM) to the US National Museum of Natural History in February 2001, including the following specimens: USNM 233997, *Microprosthema manningi* Goy and Felder (holotype); USNM 275993, *Micropros-thema granatense* Criales (holotype); and USNM 244439, Bahamas, *M. semilaeve* ovigerous female (non-type specimen).

RESULTS

Prezoeal Stage (based on *n* = 10 larvae from adult female from Sombrero Key, Florida)

Size. Total length (rostral region to tip of telson) 2.1 mm (*n* = 10).

Rostrum turned under carapace, but antennae fully extended. Appendages developed, but with setae not fully extended on any appendage. Telson well formed, similar to that of first zoeal stage (see below).

This prezoeal stage was very feeble and used its antennae to swim. The duration to first molt was less than 6 h, but only 2 of 43 survived this molt.

First Zoeal Stage (based on *n* = 10 larvae from adult female from Guana Island, BVI)

Size. Total length (tip of rostrum to posterior indentation of telson) 2.20 mm (*n* = 10). Carapace length (orbital region at base of rostrum to dorsal posterior indentation of carapace) about 0.56 mm.

Carapace (Figure 1a, b). Extending posteriorly in a more or less straight line from the rostrum. Cervical groove slight but visible just posterior to large, well developed (but sessile) eyes. Dorsally with medial rounded invagination. Minutely punctate and minutely granulate, especially on posterolateral half. Rostrum straight, unornamented, extending to level just short of distal extremity of second peduncular article of antennule.

Antennae (Figure 1d). Antennule (first antenna) biramous, but with inner ramus (endopod) so reduced as to appear as a single thick plumose seta. Outer (lateral) ramus (exopod) short, about 1/3 length of article preceding it, and with 4 plumose distal setae. More proximal articles (1 and 2) unarmed, second longer than first. Antenna (second antenna) inner ramus (endopod) short, approximately half length of exopod, and with 2 long, stout plumose setae; outer ramus (exopod) with curving inner border and nearly straight lateral border, bearing 7–11 setae from midpoint on medial border around tip and on to distolateral edge of lateral border as shown.

Mandible (Figure 2a). Broad, simple, spade-shaped, with slight tooth at dorsodistal corner. Palp lacking. Slightly asymmetrical.

Maxillule (maxilla 1) (Figure 2b). Protopod consisting of 2 lobes; anterior lobe with 2 heavy cuspidate and serrate spines and 3 plumodenticulate setae; posterior lobe with 2 stout spines, 2 plumodenticulate setae, and one heavier seta extending posteriorly from lower margin. Palp lacking.

Maxilla (maxilla 2) (Figure 2c). Endopod 2-segmented with setation 1 + 2 as illustrated. Protopod subdivided into 3 large enditic lobes, with setation 5, 3, and 4 (proximal to distal). Scaphognathite poorly developed, with 2 to 4 plumose setae and usually a stronger setose "posterior process."

Maxilliped 1 (Figure 2d). Endopod weakly 3-segmented, with setation 2, 2, 4. Exopod unsegmented, with 4 distal plumose setae. Protopod weakly 2-segmented; basal article with 2 plumodenticulate setae; distal article subdivided into 3 lobes, with setation 3, 2, 2; some setae distinctly stronger and more spinulose than others, especially noticeable on posteriormost lobe of second article.

Maxilliped 2 (Figure 2e). Basis with 4 setae arranged 1, 1, 2. Endopod 5-segmented, with setation 2, 1, 0, 2, 1 + 5. Exopod 2-segmented, with setation 1, 5.

Maxilliped 3 (Figure 2f). Very similar to maxilliped 2. Basis with 3 setae occurring singly. Endopod 5-segmented, with setation 2, 1, 0, 1, 4. Exopod weakly 2-segmented, with setation 1, 4.

Pereiopod 1 (Figure 2g). Endopod small, bearing 3 terminal, 1 subterminal, and 1 basal plumose setae. Exopod with numerous crenulations and bumps, 2-segmented, with 2 setae on proximal article and 4 setae (arranged 2 + 2) on distal article. Other pereiopods absent.

Abdomen and Telson (Figure 1b, c). Abdomen with minute teeth on posterolateral borders of somites 3 and 4, and with sharp spine extending ventrally from sternal region of somite 5 (Figure 1c). Sixth abdominal somite not distinguishable from (fused to) telson. Telson (Figure 1e, f) broadly triangular in dorsal view. Lateral corners ending in acute tooth, followed immediately by a stout, setose artic-
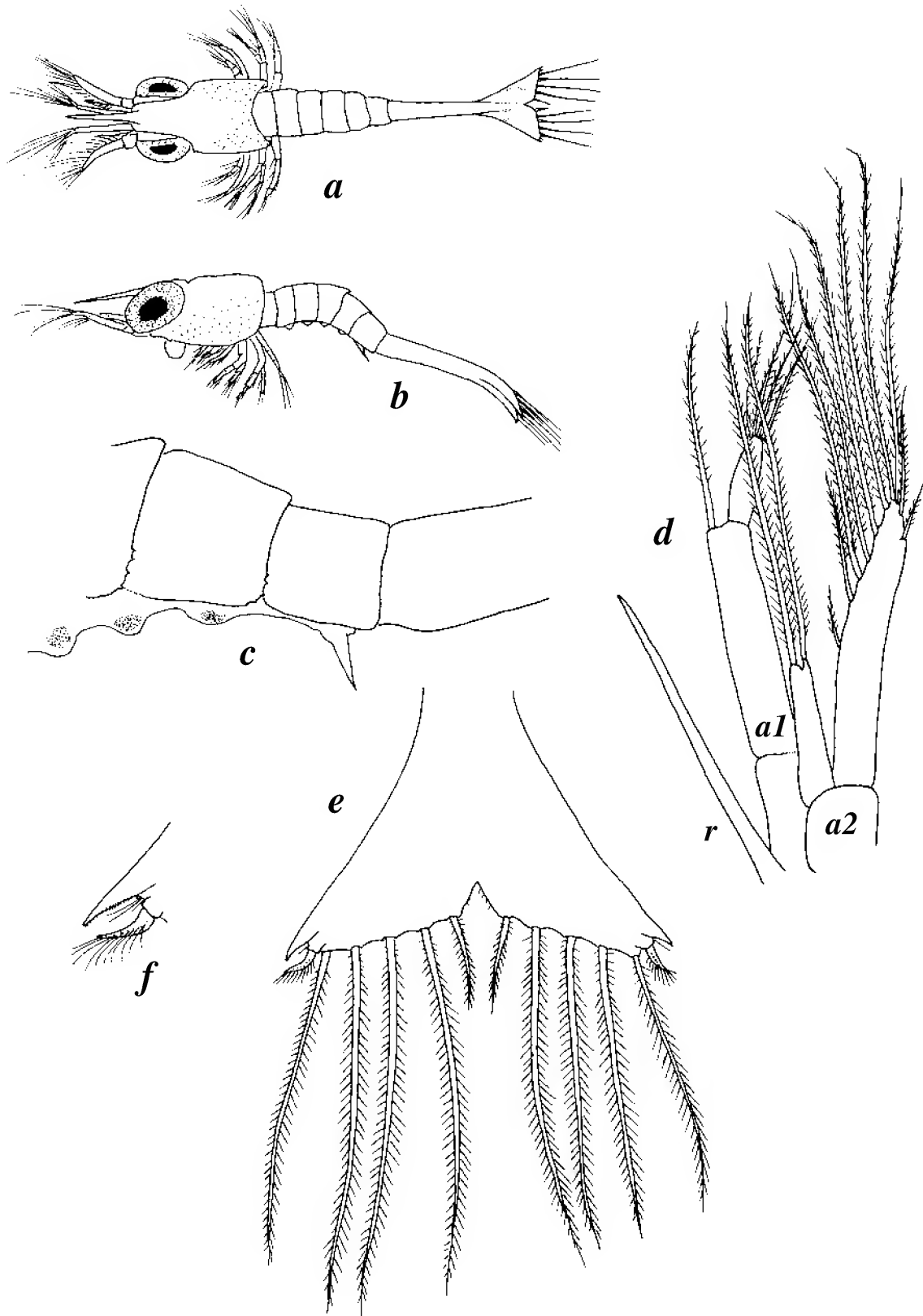
Figure 1. First zoeal stage of the stenopodidean shrimp *Microprosthema semilaeve* (von Martens, 1872) from an ovigerous female collected off Guana Island, BVI, Caribbean Sea. a, entire larva, dorsal view. b, same, lateral view. c, higher magnification of abdominal somites 3–5 and anterior of somite 6 (still fused to telson at this stage), showing acute spine extending from sternum of somite 5. d, rostrum (r), antennule (first antenna) (a1), and antenna (second antenna) (a2) in dorsal view, drawn in situ. e, telson, dorsal view. f, higher magnification of posterolateral spines of telson, dorsal view.
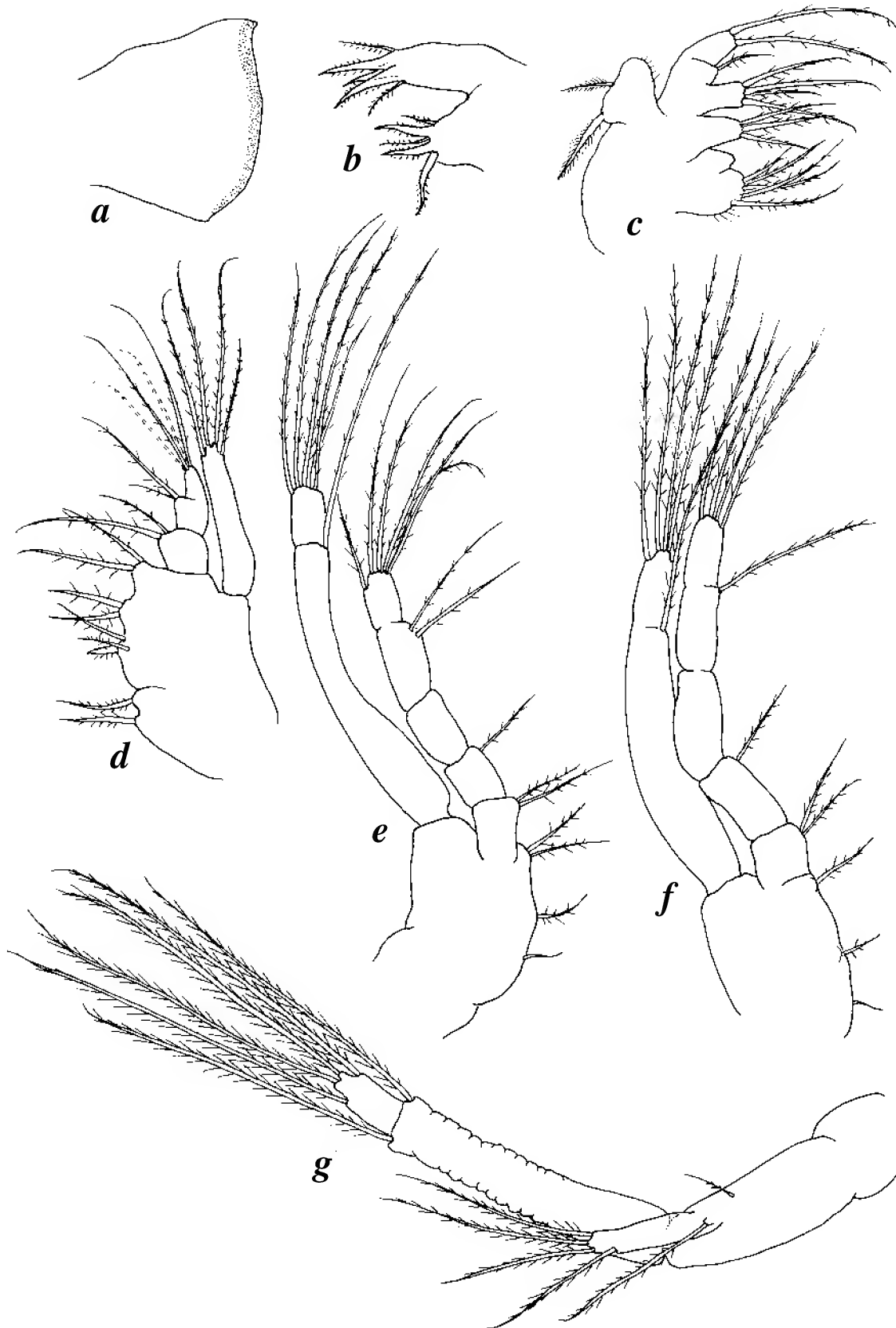
Figure 2. First zoeal stage of the stenopodidean shrimp *Microprosthema semilaeve* (von Martens, 1872), mouthparts and first pereiopod. a, mandible. b, maxillule (first maxilla). c, maxilla (second maxilla). d, first maxilliped (2 setae broken on distal article of endopod of illustrated specimen indicated by dashed lines). e, second maxilliped. f, third maxilliped. g, first pereiopod.

ulating spine that curves dorsally and laterally. Area between tooth and spine harboring single "anomuran seta," which in some cases is actually 2 or 3 thin setae (Figure 1f). Posterior border of telson with shallow sharp indentation medially, and with 4 long plumodenticulate setae and 1 considerably shorter plumodenticulate seta on each side of medial indentation.

First Zoeal Stage (based on $n = 2$ larvae from adult female from Sombrero Key, Florida)

Size. Total length (tip of rostrum to posterior indentation of telson) 2.25 mm ($n = 2$); carapace length not measured.

Antennae, maxillule, mandible, and maxilliped 1 same as described above for Guana Island specimens.

Abdominal somites 2 and 3 ending in bluntly pointed pleural spines. Telson same as above.

Maxilla. Palp bearing 2 terminal plumose setae. Protopod subdivided into 3 large endites, with setation 3, 4, and 5 (proximal to distal). Scaphognathite weak, with 5 plumose setae.

Maxilliped 2 same as above, except exopod with setation 2, 4.

Maxilliped 3 same as above, except exopod with setation 2, 4.

Pereiopod 1 same as above, except endopod with 2 basal plumose setae and exopod lacking crenulations and with setation 2, 4.

DISCUSSION

There are currently 5 described species of *Microprosthema* reported from the Caribbean and/or western Atlantic: *M. semilaeve* (von Martens, 1872); *M. manningi* Goy and Felder, 1988; *M. looensis* Goy and Felder, 1988; *M. granatense* Criales, 1997; and *M. jareckii* Martin, 2002 (see reviews by Criales 1997, Martin, 2002). The species *Microprosthema inornatum*, described by Manning and Chace (1990) from Ascension Island, South Atlantic, could potentially be in the Caribbean as well, because species of stenopodideans tend to have a relatively long larval duration (J. Goy, unpublished data) and as many as 9 larval stages (Gurney and Lebour 1941), though possibly fewer in species of *Microprosthema* (e.g., Raje and Ranade 1975). Additionally, we are aware of another undescribed species of *Microprosthema* from the Dry Tortugas, Florida (J. Goy, unpublished data).

The female *M. semilaeve* from Sombrero Key was confirmed by one of us (JWG) after examination of 80 specimens of *M. semilaeve* in the holdings of various US museums. Confirming the identification of the adult

parental female from Guana Island from which larvae were obtained proved more difficult than we anticipated. The coloration of the adult was a striking red and white, matching closely with the color description of *M. semilaeve* provided by Manning (1961) and befitting the common name "crimson coral shrimp" bestowed on it by Williams et al. (1989). However, the chelipeds of the parental female from Guana Island are more delicate and lack the large dactylar tooth as compared to "typical" *M. semilaeve* in the holdings of the USNM. Additionally, the chelae possessed a layer of fine, short, plumose setae on the inner face of the propodus. Comparison with specimens or illustrations of "true" *M. semilaeve* proved to be difficult, as that species has not been illustrated other than by Rankin (1898, side view of whole animal), Holthuis (1946, scaphocerite only), and Rodriguez (1980, partial views of carapace and abdomen). Thus, although commonly reported in the literature, this species lacks a thorough modern description. For the purposes of this report we are assuming that the crimson and white coloration is specific to this species, and thus we are referring our Guana Island specimen and its larvae to *M. semilaeve*.

The prezoeal stages obtained from the female collected at Sombrero Key are similar to the prezoeae of *Stenopus hispidus* described by Brooks and Herrick (1891). Those authors noticed a bent rostrum and underdeveloped appendages, but their prezoeal stage was non-natatory. In the present study, *M. semilaeve* prezoeae swam feebly with their antennae. It is not known if the larvae hatch as prezoea in the wild or if this was an artifact of rearing them in the laboratory, although we saw no other indications that anything was abnormal, and the ovigerous female did not appear stressed.

First stage larvae of *M. semilaeve* described herein are morphologically very similar to the larvae described by Raje and Ranade (1978) for an Indian Ocean species of *Microprosthema* (which was erroneously attributed to *M. semilaeve*). Differences include the mandible, which in *M. semilaeve* appears broadly rounded and not as toothed as in the figure provided by Raje and Ranade (1978, their figure 1d), and overall less setose appendages in the Indian Ocean larva. The first and second abdominal somites of the Indian Ocean species bear ventral projections not evident in our specimens. Finally, there are slight differences in the setal counts of some of the articles of the mouthparts and of the endopod of the first pereiopod. Although there is no doubt that the species dealt with by Raje and Ranade (1975) was not *M. semilaeve*, the slight discrepancies in the 2 larval descriptions might be simply differences in perceiving or illustrating the appendages. Such minor variation can also be attributable to variations within or

between populations of the same species or even within a single batch from one female. Interestingly, the differences noted between the description of larvae of *Microprosthema* sp. from the Indian Ocean (Raje and Ranade 1975) and our Guana Island larvae are not appreciably larger than the differences between the Guana Island (BVI) specimens and those from Sombrero Key, Florida, which we are assuming are conspecific.

Of the various stenopodidean larvae described from Bermuda plankton by Lebour (1941), their larvae A, B, and C are most similar to ours. Raje and Ranade (1978) also felt that larvae A and B of Gurney and Lebour were most similar to their description of *Microprosthema* larvae from the Indian Ocean and noted that B was "closer to *Microprosthema* than any other species described." However, Raje and Ranade also noted differences between their Indian Ocean larvae and both larvae A and B of Lebour (1941). Lebour (1941) thought that larva B, the most common larval type encountered by her off Bermuda, was possibly an undescribed species of the genus *Stenopus* (recall that the genus *Microprosthema* was not established at that time), and later in the paper she stated that "it seems probable that species A, B, C, E, and F do not belong to the genus Stenopus." Our description of larvae of *M. semilaeve* (Von Martens) differs from her larvae A and B in having a shorter rostrum, a straight (rather than recurved) spine on the sternum of abdominal somite 5, and no postorbital spines.

There was some variation observed in the first zoeae of *M. semilaeve* in the present study. Similar variation has been seen in the first zoeae of *Stenopus spinosus* (Cano 1892, Kurian 1956, Bourdillon-Casanova 1960, Seridji 1990), *S. hispidus*, *S. pyrsonotus*, and *S. cyanoscelis* (JWG, unpublished data). Lebour (1941) described a post-larva of her Stenopodid B (total length 5.0 mm) that is very similar to 3 juveniles of *M. semilaeve* (total length 7.6–8.3 mm) examined by one of us (JWG). Taking these facts into consideration, we feel that the larvae of Gurney (1936—Stenopodid I) and Lebour (1941—Stenopodid B) represent planktonic larvae of *M. semilaeve*.

ACKNOWLEDGMENTS

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Embryogenesis in the Dwarf Seahorse, *Hippocampus zosterae* (Syngnathidae)

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EMBRYOGENESIS IN THE DWARF SEAHORSE, *HIPPOCAMPUS ZOSTERAE* (SYNGNATHIDAE)

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ABSTRACT Embryogenesis of the dwarf seahorse, *Hippocampus zosterae*, was studied by scanning electron microscopy of a series of developmental stages. Stages ranged from initial cleavage of the egg through term embryos. Embryos hatch from their egg envelopes about midway through development, yet remain nestled in stromal chambers of vascularized epithelium within the male brood pouch until their yolk reserves are consumed. The difference in body shape between the pipefish and seahorse first becomes discernible during mid-development, just before hatching. At this stage, embryos begin to develop their characteristic prehensile tail in contrast to the straight body and typical caudal fin of most species of pipefish. Post-hatching, 'yolk-sac' larvae have a well developed head, that is set at a right angle to the body axis, and fully formed fins. As seahorse embryos approach term, lepidotrichia calcify, and the prehensile tail is capable of muscular contraction. Dermal scutes first appear at this stage and ossify in the term embryo. The dermal armor is then fully formed and functional. At term, the yolk reserves have been depleted, and the young are released from the brood pouch as free-swimming, free-feeding miniature versions of the adults.

INTRODUCTION

Fishes of the family Syngnathidae, which includes seahorses and pipefishes, display a number of specialized anatomical features that are characteristic of the group (Jungerson 1910, Khalil 1979, Fritzsche 1984). Within the Syngnathidae, seahorses are distinguished from pipefishes by the orientation of the head normal to the body axis and by a prehensile tail. It is, however, the peculiar reproductive mode of brooding their embryos on the skin of the male abdomen that collectively distinguishes the Syngnathidae from other syngnathiforme fishes (Nelson 1994). Developing eggs are either attached to the ventral surface of the male's body, or the eggs and free embryos are contained in a pouch that is formed from the epidermis of the abdomen.

In the putative ancestral form of male skin-brooding in pipefishes (Herald 1959), the female transfers eggs via her ovipositor to the caudal part of the male's body in a region posterior to the vent (*Solegnathus, Phyllopteryx,* and *Phycodurus*) or to the ventral abdominal region just anterior to the vent (*Syngnathoides* and some *Dunckerocampus*). The eggs adhere to the male and are brooded. In this primitive condition the eggs rest in depressions of modified epidermis or 'stromal tissue' that develops on the male abdomen. No further envelopment of the embryos occurs, and free-swimming young hatch directly from egg envelopes into the water. In the derived condition of skin-brooding (seahorses and nearly all pipefish species), eggs are oviposited into a male brood pouch that is formed from the epidermis along the ventro-abdominal surface. Depending on the degree of closure of the brood pouch,

eggs may be partially sealed or completely sealed within this brood pouch. Eggs hatch within the brood pouch and are subsequently afforded some degree of paternal care prior to their release as free-swimming young. The brood pouch is lined with stromal tissue, a simple, cuboidal epithelium that becomes spongy in texture and heavily vascularized after oviposition (Wetzel and Wourms 1991). As development proceeds, the egg envelope of each embryo splits open. The hatched embryo is then nestled within the stromal tissue, where it remains until its yolk is absorbed.

The period of gestation within the male brood pouch is both temperature related and species specific. After a gestation of 30–50 d duration, young are released from the brood pouch either through a longitudinal fissure (pipefishes, with the exceptions of *Apterygocampus* and *Acentronura*) or through an antero-medial opening of the pouch (*Hippocampus, Apterygocampus,* and *Acentronura*). After parturition, the internal stromal tissue of the brood pouch returns to the normal pre-vascularized condition (Wetzel 1995). Free-swimming young have adult body form, except that males lack their characteristic brood pouch which will not be evident for an additional 3 to 4 weeks.

There are contemporary accounts on the anatomy and developmental morphology of the Syngnathidae (Sudarsan 1968, Blake 1976, Azzarello 1990). Although each of these studies was comprehensive in its own right, none provide an overview of the process of development from early cleavage through free-living juveniles. This study describes, using a series of scanning electron micrographs, embryogenesis of the dwarf seahorse, *H. zosterae.*

Materials and Methods

Study specimens

Preserved museum specimens and newly collected live specimens were combined to assemble a series of seahorse embryos that represent the major stages of embryonic development. Museum specimens of the dwarf seahorse, *H. zosterae* Jordan and Gilbert, were obtained from the collections of the Gulf Coast Research Laboratory Museum (GCRL specimen #10560—collected Lee County, Florida, sta. 69-234, Wang/Jackson), Ocean Springs, Mississippi, and from the California Academy of Sciences (CAS specimen #1687—collected Key West, Florida, 4/18/71, D. Smith), San Francisco, California. Additional embryos of *H. zosterae* were the offspring of specimens maintained in aquaria.

Microscopy

Mature ova were removed from the germinal ridge, at the ovarian side of the oviducts excised from museum specimens of *H. zosterae*. To obtain embryos from live specimens, gravid males were anesthetized in a 1000 ppm solution of MS-222 (ethyl m-aminobenzoate methanesulfonate, Crescent Research Chemicals, Inc.) in seawater. Embryos were excised by a lateral incision through the brood pouch, then placed into a 2.5% glutaraldehyde-1.6% paraformaldehyde fixative in 0.1 M Sorensen's phosphate buffer (pH 7.4). Fixations were carried out at room temperature for 2 h, followed by two 10-min rinses in 0.1 M Sorensen's buffer. Fixed embryos that were used for descriptions of the developmental stages were manually dechorionated prior to dehydration. Specimens for SEM were dehydrated through absolute ethanol, critical point dried, and gold-coated for 400 sec. SEM observations were made at an accelerating voltage of 15kV with a JEOL 35cf SEM.

Results

The stages of embryonic development

Description of the development of the dwarf seahorse, *H. zosterae*, is based on 8 different developmental stages that ranged from the 2-blastomere stage through term (Figure 1).

Unfertilized eggs: Mature infertile ova are slightly 'pear-shaped' (Hudson and Hardy 1975). They measure about 1100 μm in diameter along the long axis. Ova of other syngnathid species have been described as ellipsoidal or ovoid (Mito 1961). The chorion is transparent and its surface is devoid of any membrane projections (Wetzel and Wourms 1991). The egg envelope measures 0.86 μm thick and forms a homogeneous, non-fenestrated barrier around the egg. The individual eggs are transparent, vary in color from light amber to deep orange, and contain several oil droplets throughout the yolk (Gudger 1905). The vitelline membrane adheres closely to the ovum and is not readily discernible. No newly fertilized eggs were found.

Early cleavage

At the 2-cell stage, the blastodisc, yolk cytoplasmic layer, and deuteroplasm can be differentiated. The yolk cytoplasmic layer extends all around the surface, almost to the equator of the egg, covering the deuteroplasm. The lower half of the egg is formed of deuteroplasm and contains numerous vesicles, which are larger but less numerous than in the nonfertilized egg, as well as large oil globules. Cleavage is meroblastic, and the first division results in 2 equivalent sized blastomeres, each measuring about 180 μm in diameter (Figure 2a). Cleavage continues to form 16 blastomeres (Figure 2b) connected by cytoplasmic bridges along their cell boundaries (Figure 2c). Blastomeres at the 16-cell stage measure about 78 μm in diameter. They do not form the parallel rows that are often seen in typical teleostean early development (Armstrong and Child 1965). Rather, the margins of the cells form an irregular, ovoid shape on the surface of the yolk. An elaborate network of cytoplasmic processes (Figure 2d) appears along the outer edges of the blastoderm where individual blastomeres are in contact with the yolk cytoplasmic layer.

During late cleavage the blastoderm of *H. zosterae* (Figure 2e) is a discoidal mass that measures about 390 μm in diameter and lies on top of the deuteroplasm. Cleavage appears to proceed in a typical teleostean pattern, i.e., the blastomeres are about equal in size, somewhat flattened, and slightly raised above the surface of the blastoderm. Individual cells of the late-stage blastoderm measure about 15 μm in diameter (Figure 2f). The periphery of the blastoderm has a somewhat uneven outline, due to irregular contact of the blastomeres with the yolk cytoplasmic layer. No surface extensions were found on the individual cells that make up the blastoderm.

Tail-bud embryos

At the tail-bud stage of development (Figure 1b, 3a), the embryonic axis is about 1500 μm in length and is aligned along the midline of the embryonic shield. As embryogenesis proceeds, the embryo continues to elongate, yet remains coiled around the yolk mass (Figure 3d). The anterior end is slightly broadened and is clearly differentiated into the cephalic region. Regions of the brain are apparent, and there is a clear line of demarcation between
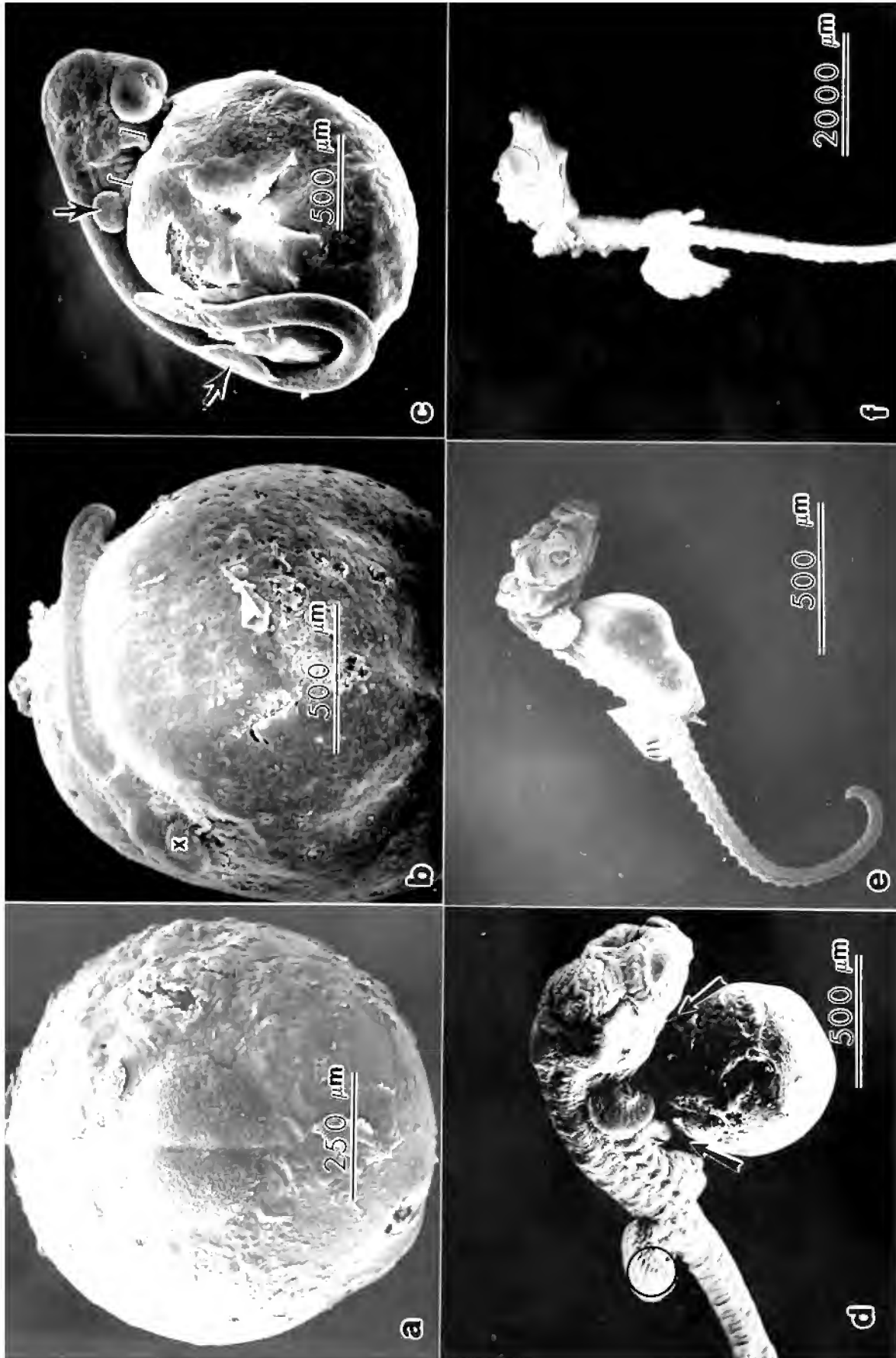
Figure 1. Major developmental events in the pre-hatching (a, b, and c) and post hatching (d, e, and f) *Hippocampus* embryos. a) Cleavage of the *Hippocampus* ovum, 89X. b) The tail-bud embryo optic vesicles (x), 52X. c) The dorsal-fin bud (posterior arrow), pectoral-fin bud (anterior arrow), branchial arches (brackets), and the mandibular arch differentiating into the lower jaw, 36X. d) 'Yolk-sac' larva with lepidotrichia (circle), 47X. e) The near-term embryo, 57X. f) The term neonate, 11X.
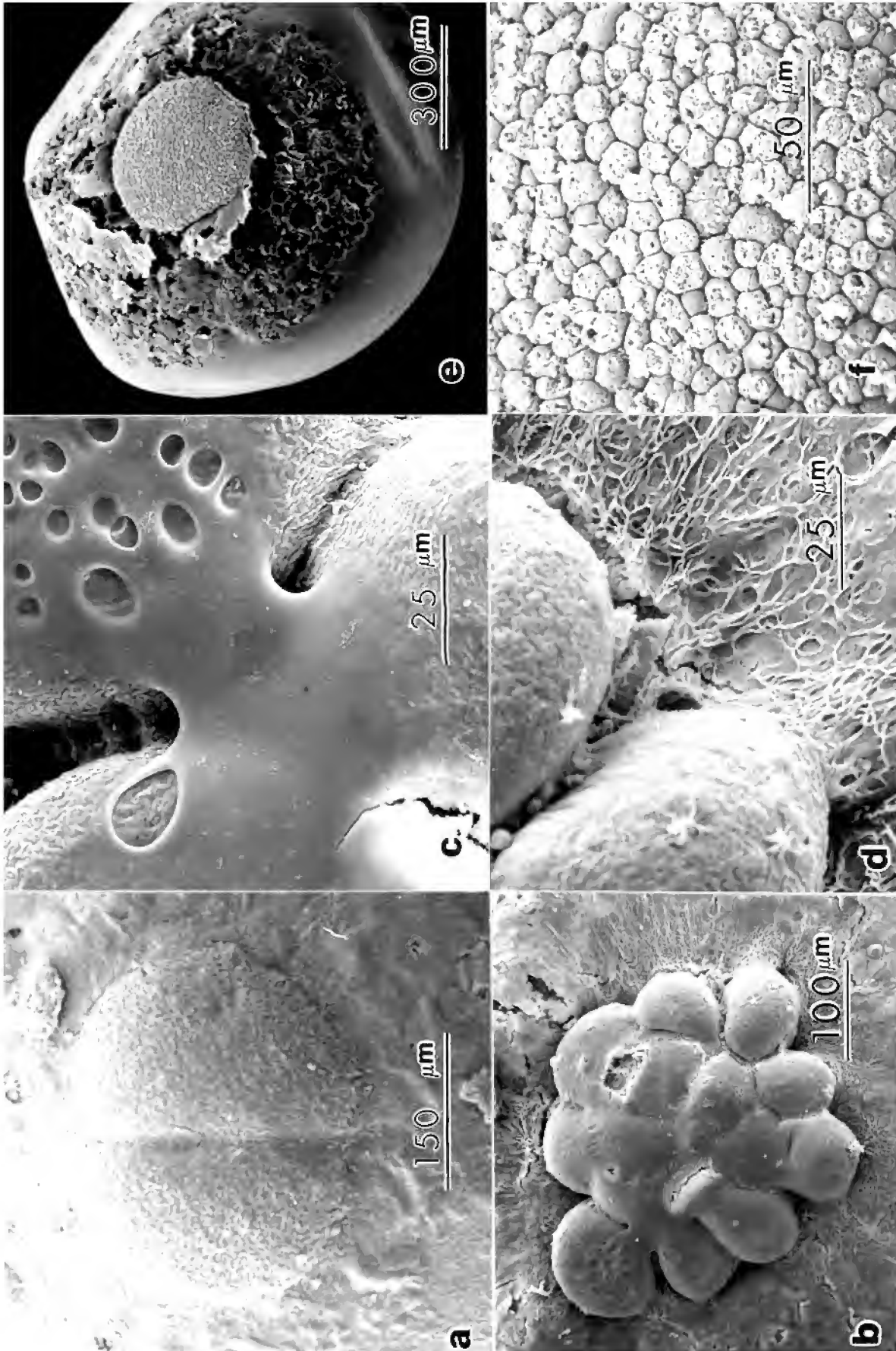
Figure 2. Cleavage of the *Hippocampus* ovum: Two blastomeres (2a) through formation of the blastoderm (2e). a) Individual blastomeres at the two-cell stage, 167X. b) Blastomeres at the 16-cell stage, 160X. c) Each cell is connected by a protoplasmic bridge (2c) along its membrane, 800X. d) The periblast where cells contact the yolk cytoplasmic layer, 720X. e) The discoidal blastoderm (2f) that rests on the deuteroplasm, 68X. f) 473X.
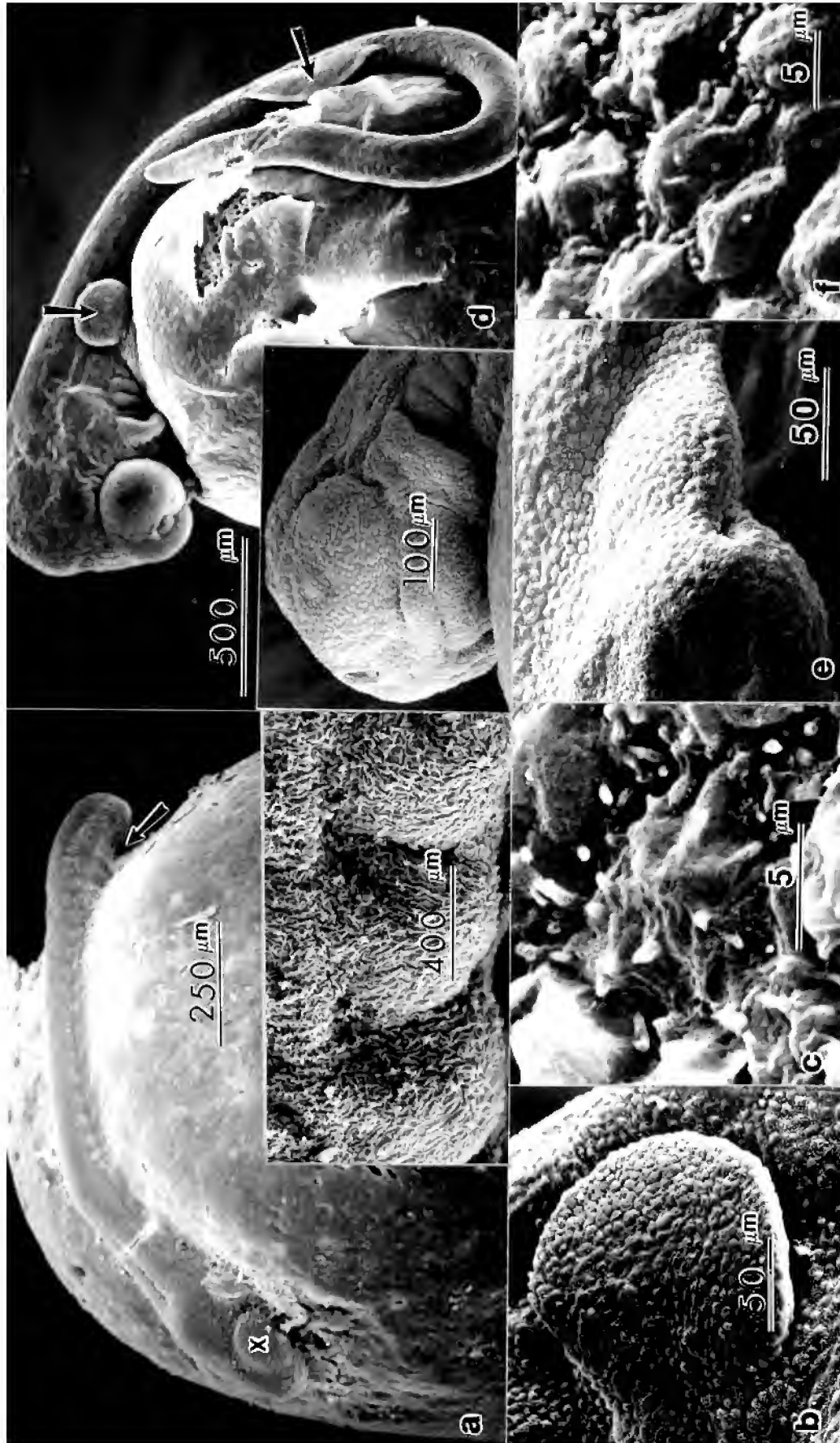
Figure 3. a) The tail-bud: The caudal region is raised from the surface of the deuteroplasm (arrow). Myomeres (inset) developing in the lateral body, 86X; inset 400X. b) Pectoral-fin buds have emerged, 320X. c) Surface of the fins, 4400X. d) The lens (inset) has differentiated from the optic vesicle, 58X; inset 120X. e) The anal fin emerging as a swelling posterior to the vent, 400X. f) Surface of the developing anal fin, 3600X.

the embryonic diencephalon and metencephalon. Optic vesicles (Figures 1c, 3a (x)) are present on each side of the diencephalon but the lens placodes are not yet developed. Branchial arches have emerged (Figure 1c, brackets) and the anteriormost arch has begun differentiating into the mandibular arch that will form part of the jaw. Pectoral-fin buds are present (Figure 3b) but lepidotrichia within the fins have not yet developed. No surface amplifications are present on the fins (Figure 3c). A series of 12 to 14 myomeres are aligned along the lateral body region (Figure 3a inset). The posterior end of the body is slightly raised and laterally flattened to form the caudal-fin bud. The caudal-fin bud is slightly elevated from the surface of the yolk mass (Figure 3a, arrow). Caudal fins that are characteristic of almost all pipefishes do not develop from the fin bud. Instead, the caudal bud eventually elongates into a prehensile tail. The anal fin first appears as a swelling posterior to the vent (Figure 3e). No surface amplifications are seen on the emerging anal fin (Figure 3f). Embryos of *H. zosterae* are 5300 μm in length during mid-development (Figures 1c, 3d) and still reside in their egg envelopes. At this phase, a distinct dorsal-fin bud is present (Figure 1c, posterior arrow). Paired pectoral-fin buds also appear (Figure 1c, anterior arrows). Although the head region is clearly delineated, the rostrum has not yet emerged and the head is connected to the deuteroplasm (Figure 3d inset). The mesencephalon is greatly enlarged relative to the diencephalon and metencephalon brain regions. The eye lens vesicles reside in the center of the greatly expanded optic cups and the eye is pigmented. Auditory placodes have developed lateral to the metencephalon. The anterior arch is differentiating into the buccal apparatus.

Yolk sac 'larva'

Although hatching from the egg envelope occurs at the 'yolk-sac larva' phase (Hardy 1978) (Figures 1d, 4a), the embryo will remain nestled within the stromal tissue of the brood pouch until the yolk reserves are exhausted. This terminal phase of development is characterized by morphogenesis of the jaw, growth of the dorsal and pectoral fins, and decrease in size of the yolk sac as the yolk reserves are utilized. Pectoral and dorsal fins are broadened and flattened, and their lepidotrichia are differentiated (Figure 4b, circle). Contact of the embryo with the yolk sac is limited to its thoraco-abdominal region. The entire prehensile tail and the anterior half of the head are free. In embryos, at this stage, that were removed from the brood pouch the tail did not respond to mechanical stimulation. The anal fin begins to develop (Figure 3e). No surface amplifications are found on the emerging anal fin (Figure 3f). The vent posterior to the anal fin is closed. Two trans-

verse cartilages form from the anterior arches and represent the initial formation of the upper (maxillary) and lower (mandibular) jaws (Gill 1904). The upper jaw is straight, whereas the lower jaw, which is broadly triangular in shape, curves upward to partially cover the median portion of the upper jaw. The branchial arches are covered by an operculum.

Near-term embryos

In the near-term embryo (Figure 1e, 4c), the head is completely free from the surface of the yolk sac, and the jaws elongate because of growth of the ethmoid and quadrate cartilages (Azzarello 1990). The characteristic posture of the seahorse head, i.e. oriented at about 90 degrees to the body axis, is apparent at this stage. This differs from pipefishes, wherein the angle of the head remains in line with the elongate body axis. The anal fin is formed (Figure 4d) and the vent is open. Microvilli are present on the anal fin (Figure 4e). Lepidotrichia within the dorsal and paired pectoral fins, as well as the anal fin, are fully formed, although not yet fully calcified (Wetzel 1995). The prehensile tail is capable of muscular contraction. Yolk reserves are nearly consumed, but the extraembryonic yolk sac is still evident as a slight swelling from the abdominal region. Chromatophores are developed along the lateral body surface, except for the fins. Dermal armour, characteristic of *Hippocampus* and comprised of a series of interlocking epidermal plates, first appears at this stage as small scutes along the lateral body (Figure 4c inset). The largest scute measures about 190 μm in diameter at the base and they are spaced about 240 μm apart. Each dermal scute is covered by an epidermal layer.

Term embryos

In the term embryo (Figure 1f, 4f) internal yolk reserves are completely exhausted and there is no notable protrusion of the extraembryonic yolk sac. The young are able to feed freely upon release from the brood pouch. The prehensile tail is fully capable of adhering to the substrate and the extrinsic eye musculature is fully functional. Following parturition, the lepidotrichia within the fins become fully calcified and rigid (Wetzel 1995). The dermal scutes of the body armour are now greatly enlarged, 360 + 38 μm, and are in contact with adjacent scutes along their bases. The calcified dermal crowns erupt through the epidermis and appear as a series of spines along the lateral body and down the tail (Figure 4f inset). Neuromasts (Figure 4g) develop along the rostrum. Pigmentation increases considerably beyond that of the near-term embryo, except for a region of the abdomen near the vent. The characteristic male brood pouch is not yet evident, but
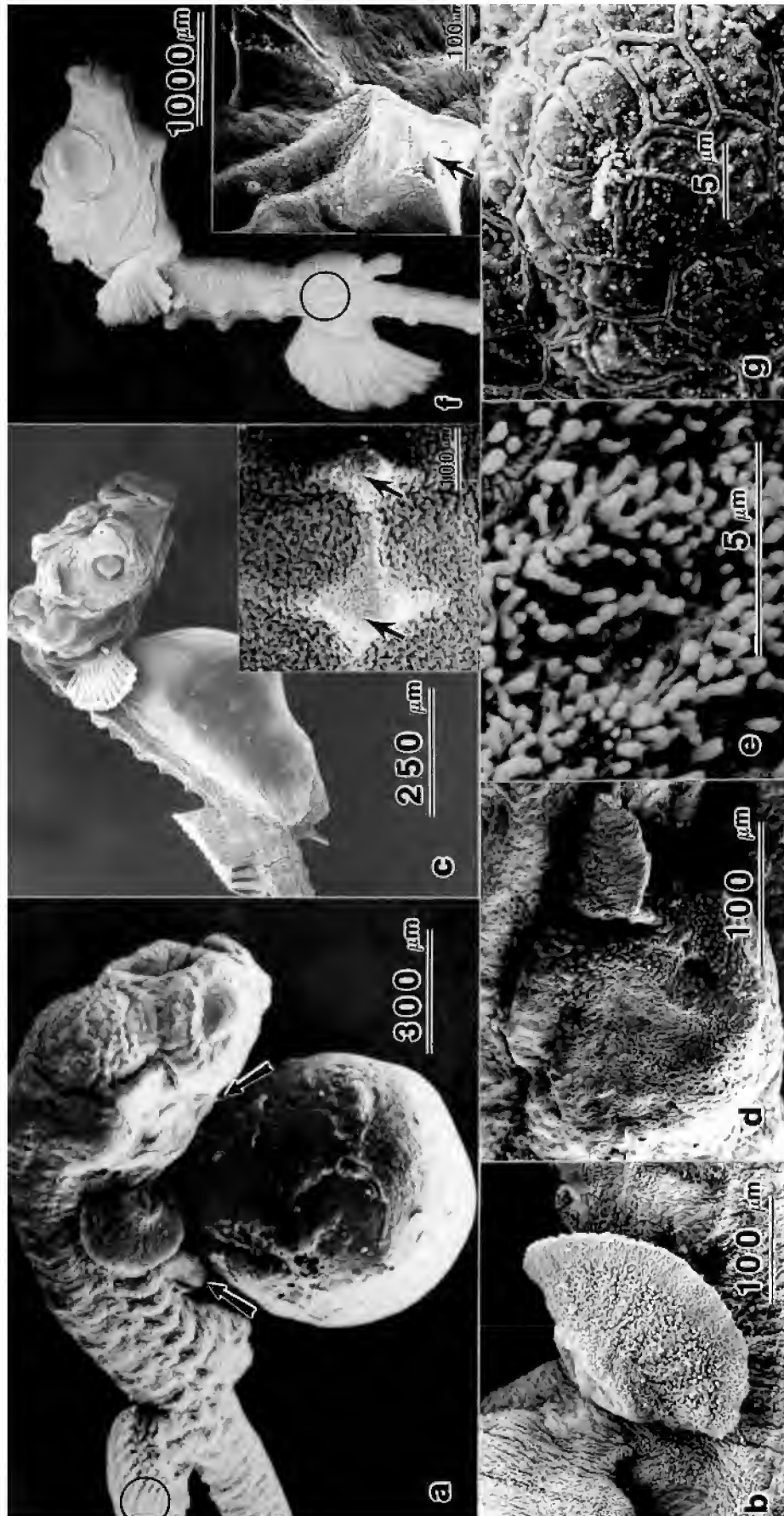
Figure 4. a) The yolk-sac larva: The abdominal and head regions are free from the surface of the yolk (arrows), 74X. b) Lepidotrichia (4a circle) within the dorsal fin, 180X. c) Dermal scutes (arrows) along the lateral surface of the tail, 93X; c inset 107X. d) The anal fin and the open vent, 260X. e) Microvilli on the anal fin, 7800X. f) Fully formed scutes (circle and inset) in the term neonate, 20X; inset 116X. g) Neuromasts along the rostrum of the neonate, 2600X.

within 3 to 4 weeks it will emerge in what is now a lightly pigmented region of the abdomen (Bellomy 1969). Upon release from the adult brood pouch, term embryos measure about 8600 + 158 μm.

DISCUSSION

Comparison of seahorse and pipefish development

Scanning electron micrographs of 6 distinct stages in the development of *H. zosterae* provide a basis for comparing embryogenesis of seahorses with that of other syngnathid fishes. Based on our observations and previous reports on pipefishes (Gudger 1905), there are no significant morphological differences in early development, i.e. cleavage through tail-bud embryos, between seahorse and pipefish embryos. Embryos of *Hippocampus* can first be distinguished from other syngnathid embryos midway through development, i.e., just prior to hatching. At hatching, yolk-sac larvae have a well developed head and fully formed pectoral fins. At this stage, a developing caudal fin is evident in pipefish embryos, whereas seahorse embryos lack any indication of a caudal-fin fold. In the more advanced yolk-sac larval stage, which we refer to as the near-term embryo, the prehensile tail of the seahorse is fully formed and capable of muscular contraction. Orientation of the head of the seahorse embryo at a 90° angle normal to the body axis also occurs at near-term whereas the head of pipefishes continues to develop in line with the body axis. In seahorses, their characteristic dermal armor has completely formed prior to release from the brood pouch (vida infra). In summary, major morphological differences between seahorses and pipefishes become evident after hatching from the egg envelopes. In the case of the seahorse, the subsequent sojourn in the brood pouch not only is the time period during which these differences are established, but it also allows the young seahorse to develop to a morphologically more advanced state than the newly hatched pipefish, i.e., seahorse young are precocial.

The brood pouch and dermal calcification

Embryos of syngnathid fishes that are not enclosed within a brood pouch, such as the pipefishes *Syngnathoides, Phycodurus, Phyllopteryx,* and *Solegnathus,* hatch and immediately enter the surrounding water as functional, free swimming young. In contrast, embryos of species that retain their eggs within a pouch, hatch from their egg envelopes prior to the completion of incubation and then continue to develop for an additional 6 to 10 days within the male's pouch (Takai and Mizokami 1959). During this time, additional materials not provided during oogenesis can be sequestered from the pouch fluid by the

young. Embryos of *H. zosterae* hatch from their egg envelopes before embryogenesis is complete and remain nestled in stromal chambers of vascularized epithelium within the male brood pouch until their yolk reserves are consumed. Because supplemental nutrients are not transferred to the developing embryo by the male (Wetzel and Wourms 1991), maintenance of the embryos within the brood pouch would appear to serve a different function. In an earlier study (Wetzel and Wourms 1991), we noted a marked and progressive decline in organic weight during development, representing the catabolism of yolk reserves. In contrast, while inorganic weight also declines steadily to the hatching stage, there is an increase in weight during the post-hatching, terminal phase of development, so marked that it results in a net increase in total weight of the term embryo. Elevated levels of calcium ions have been found in *Hippocampus* brood pouch fluid (Linton and Soloff 1964). Furthermore, the emergence of the dermal skeleton of the seahorse embryo is associated with the accumulation of calcium within the brood pouch during the post-hatching phase of development (Wetzel 1995). Dermal scutes that first appear in the near-term embryo become fully ossified in the term embryo so that the dermal armor is completely formed prior to 'birth.' Calcification of the dermal skeleton while in the pouch confers a subsequent advantage of protection to the young seahorse, because they will be heavily armored upon their release from the brood pouch.

ACKNOWLEDGMENTS

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Morphological Characteristics of the Carapace of the Hawksbill Turtle, *Eretmochelys imbricata*, from Cuban Waters

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MORPHOLOGICAL CHARACTERISTICS OF THE CARAPACE OF THE HAWKSBILL TURTLE, *ERETMOCHELYS IMBRICATA*, FROM CUBAN WATERS

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ABSTRACT Hawksbill turtles, *Eretmochelys imbricata* (Linnaeus, 1766), from Cuban waters of the Caribbean were analyzed to determine the relationships between straight carapace length (SCL) and either straight carapace width (SCW) or body weight (Wt). The regression equations were $SCW = 0.9136(SCL)^{0.951}$ ($R^2 = 0.923$, $n = 315$) and $Wt = 4.17 \cdot 10^{-4}(SCL)^{2.68}$ ($R^2 = 0.798$, $n = 289$), respectively. The regression equations between the first costal width (C1W) and either SCW or Wt were $SCW = 3.223(C1W)^{0.847}$ ($R^2 = 0.919$, $n = 156$) and $Wt = 1.416 \times 10^{-2}(C1W)^{2.426}$ ($R^2 = 0.740$, $n = 133$), respectively. There was no difference in slopes of the C1W-SCL relationship between wild and captive raised turtles as analyzed by ANCOVA. Thus, I pooled the group data and re-calculated the C1W and SCL relationship as $SCL = 4.353(C1W)^{0.848}$ ($R^2 = 0.953$, $n = 340$). This result indicated that SCL measurements could be estimated based on C1W measurements and that the C1W-SCL relationship could be applied to captive raised or wild hawksbills. It is clear that the SCL-SCW and C1W-SCW relationships were more similar to the relationship in the hawksbill turtles from Puerto Rican waters than to those captured in Australian waters, although there was no significant geographic difference between specimens from the Caribbean and Australian

INTRODUCTION

The external morphology and sizes of marine turtles offer a great amount of useful biological information. Comparisons of the morphologies among populations provide a better understanding of evolutionary and genetic relationships, whereas comparisons of the body sizes among individuals and populations help to clarify physiological and ecological relationships. It has been reported that body size is connected to body temperature (Spotila and Standora 1985), metabolic rate (Prange and Jackson 1976), growth rate (Bjorndal and Bolten 1988), and clutch size (Witzell 1985). Because it is relatively easy to measure the morphological characteristics of marine turtles, there have been a number of studies of carapace size in various populations of the hawksbill turtle, *Eretmochelys imbricata* (Linnaeus, 1766) (Witzell 1985). However, because of the difficulty of gathering specimens and determining the sex of immature turtles, these studies often had only a small sample size and hadn't dealt with the distinction between females and males. Morphological studies of the carapace in the hawksbill have been compiled for Australia (Limpus 1992) and Puerto Rico (van Dam and Diez 1998). Until now, there has been no report on carapace shapes in turtles found in Cuban waters. Many wild adult hawksbill carapaces have been measured in Cuba but no immature turtle carapace measurement data are available. The goal of this study was to collect more data of wild and captive raised turtles, to analyze these data altogether, and to discuss geographical variations in the carapace morphology of hawksbill turtles.

MATERIALS AND METHODS

To determine the relationships between straight carapace length (SCL) and straight carapace width (SCW), SCL and weight (Wt), and the first costal width (C1W) and SCW or between C1W and Wt, I used measurement data from 315 hawksbill turtles captured by fishery net in Cuban waters from 1995 to 1998. Thirty-two of the 315 were captured from Doce Leguas Key, southwest of Cuba in 1995 and 1998, 48 from Nuevitas, northeast of Cuba in 1995 and 1996, and 235 from Isla de Pinos, southeast of Cuba in 1996. For the relationship between C1W and SCL, I added measurements from 184 captive raised hawksbill turtles that had hatched on Doce Leguas Key and were raised at breeding facilities on Isla de Pinos. I did not classify turtles by sex because there is no sexual difference in the hawksbill carapace (Limpus 1992).

I measured select morphometrics of 156 wild and 184 captive raised hawksbill turtles (Figure 1). Measuring sites were SCL, SCW, Wt, and C1W (Figure 1). Vernier calipers (± 0.5 cm) were used to measure SCL and SCW, C1W was measured using a tape measure (± 0.1 cm) from whole turtle's carapaces, and Wt was measured using a spring scale (up to 20 kg ± 0.05 kg, from 20 kg to 90 kg ± 1kg) from turtles which were either drowned within 24 hrs or alive (see Figure 2).

I estimated the relationships between $\log_{10}$ SCL, $\log_{10}$ SCW, or $\log_{10}$ Wt and $\log_{10}$ C1W by calculating the allometry equation $Y = aX^b$ for the data presented in Table 1. Then I compared slopes of the regression lines $\log_{10}$ SCL vs $\log_{10}$ C1W between wild and captive raised individuals
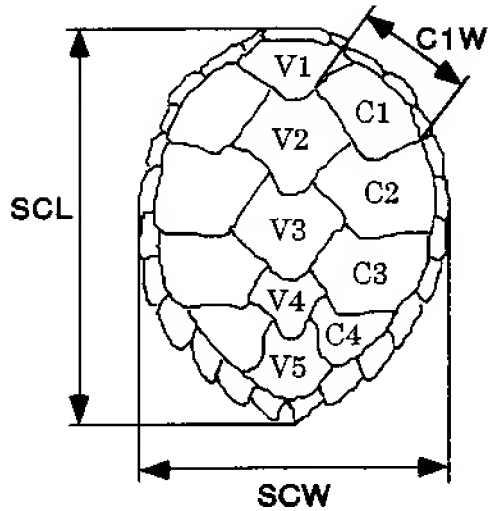
Figure 1. Measurements of hawksbill carapace. Straight carapace length (SCL) was measured between the nuchal notch to posteriormost marginal tip carapace length. Straight carapace width (SCW) was the maximum carapace width, and the first coastal scute width (C1W) was measured as the curved width of first costal.

with an analysis of covariance (ANCOVA), using $\log_{10}$ SCL as the coviarate.

RESULTS

The relationships between SCL and either SCW or Wt were: SCW = 0.9136(SCL)$^{0.951}$ ($R^2 = 0.923$, $n = 315$), and Wt = 4.17 x 10^{-4} (SCL)$^{2.68}$ ($R^2 = 0.798$, $n = 289$), respectively (Table 2). The relationships between C1W and either SCW or Wt were: SCW = 3.223(C1W)$^{0.847}$ (R^2

= 0.919, $n = 156$) and Wt = 1.42 x 10^{-2} (C1W)$^{2.43}$ ($R^2 = 0.740$, $n = 133$), respectively (Table 2).

Although the SCL range was different between wild and captive raised turtles (Figure 2), the C1W and SCL regression equations of those relationships showed no difference when compared with ANCOVA ($P > 0.05$, Figure 3). Thus, I pooled data from the wild and captive raised individuals and re-examined the relationship. The resulting equation was: SCL = 4.353(C1W)$^{0.848}$ ($R^2 = 0.953$, $n = 340$).

DISCUSSION

The relationships between SCL and SCW, SCL and Wt, C1W and SCL, and C1W and SCW were compared with those from the hawksbill population in the Puerto Rican sea of the Caribbean (van Dam and Diez 1998) and the Australian sea (Limpus and Miller 1990, Limpus 1992). I used the regression equations from the literature in which ranges of carapace sizes were noted as referenced. In the Australian sea, the curved carapace length (CCL) was used to estimate SCL, using SCL = 0.9355 × CCL + 0.4486 (Limpus 1992). As expected, the SCL-SCW relationship of the Cuban hawksbill turtles was closer to those collected near Puerto Rico than those from Australian waters (Figure 4a). The SCL-Wt relationships of the turtles from all 3 areas, however, were not significantly different (Figure 4b). There was also no difference between C1W and SCL among these regions (Figure 4c), although the C1W-SCW relationships from Cuban and Puerto Rican hawksbill turtles were more similar (Figure 4d) than any other comparison.
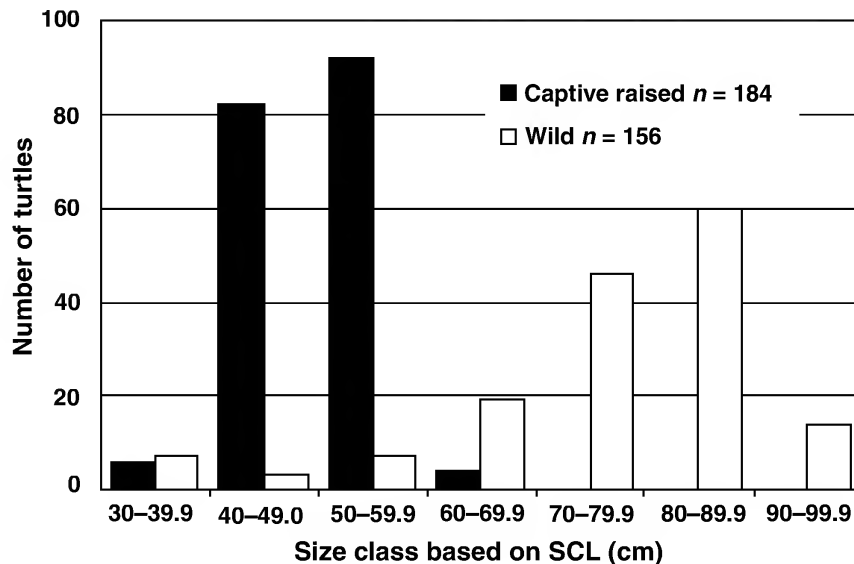

Figure 2. Straight carapace length (SCL) distribution of wild and captive raised hawksbill turtles collected from Cuba.

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TABLE 1

Information of the mean, standard deviation (SD), maximum, and minimum values of each measurement by group. Straight carapace length (SCL), straight carapace width (SCW), weight (Wt), and the first costal scute width (C1W). ( )* indicates the measurement locations for calculation of the descriptive statistics.

		Group	*n*	Mean	SD	Max.	Min.
SCL	(SCW)*	Wild	315	64.5	13.9	89.3	19.7
	(Wt)*	Wild	289	65.9	12.2	89.3	19.7
	(C1W)*	Wild(Captive raised)	340(184)	52.6	16.7	87.2	22.1
SCW	(Wt)*	Wild	315	48.1	10.3	71.0	15.4
	(C1W)*	Wild	156	49.3	10.0	66.0	15.5
Wt	(SCL)*	Wild	289	37.1	16.6	84.0	1.0
	(C1W)*	Wild	133	42.1	15.2	84.0	6.0
C1W	(SCL)*	Wild(Captive raised)	340(184)	19.0	7.0	35.4	6.9
	(SCW)*	Wild	156	25.1	5.6	35.4	6.9
	(Wt)*	Wild	133	26.5	3.7	35.4	14.5

The SCL-SCW ratio (SCL/SCW = body shape) of hawksbill turtles collected near Puerto Rico tends to be greater than those collected near Australia (Limpus and Miller 1990) and southeast Africa (Hughes 1974, van Dam and Diez 1998). Hawksbill turtles collected near Cuba had similar body shape to those collected near Puerto Rico (Figure 4a). Although there is about 12%, 30%, and 31% mtDNA haplotype frequencies of Puerto Rican nesting populations in the southeast, southwest, and northeast populations of Cuban hawksbills, respectively (Díez-Fernández et al. 1998), there is little genetic exchange between the Cuban, Puerto Rican and Australian turtles (Bass et al. 1996). The SCL-SCW relationship showed a conspicuous geographic difference.

The C1W-SCL relationship varies little among Australian, Puerto Rican, and Cuban turtles. In other

TABLE 2

Regression equations in the form $Y = aX^b$ for estimating (Y) from selected scale measurements (X).

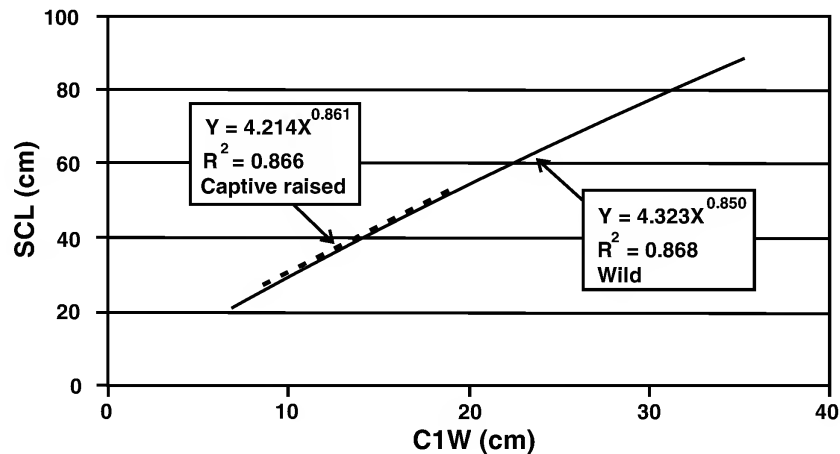| X	Y	a	b	*n*	R^2	F	*P*
SCL	SCW	0.914	0.951	315	0.923	3759	$P < 0.01$
SCL	Wt	4.17×10^{-4}	2.68	289	0.798	1128	$P < 0.01$
C1W	SCL	4.353	0.848	340	0.953	6836	$P < 0.01$
C1W	SCW	3.223	0.847	156	0.919	1747	$P < 0.01$
C1W	Wt	1.42×10^{-2}	2.43	133	0.740	372	$P < 0.01$

Figure 3. Plot of the C1W-SCL relationship between wild and captive raised turtles. The dotted line represents the regression of captive raised turtles whereas the solid line represents wild turtles.
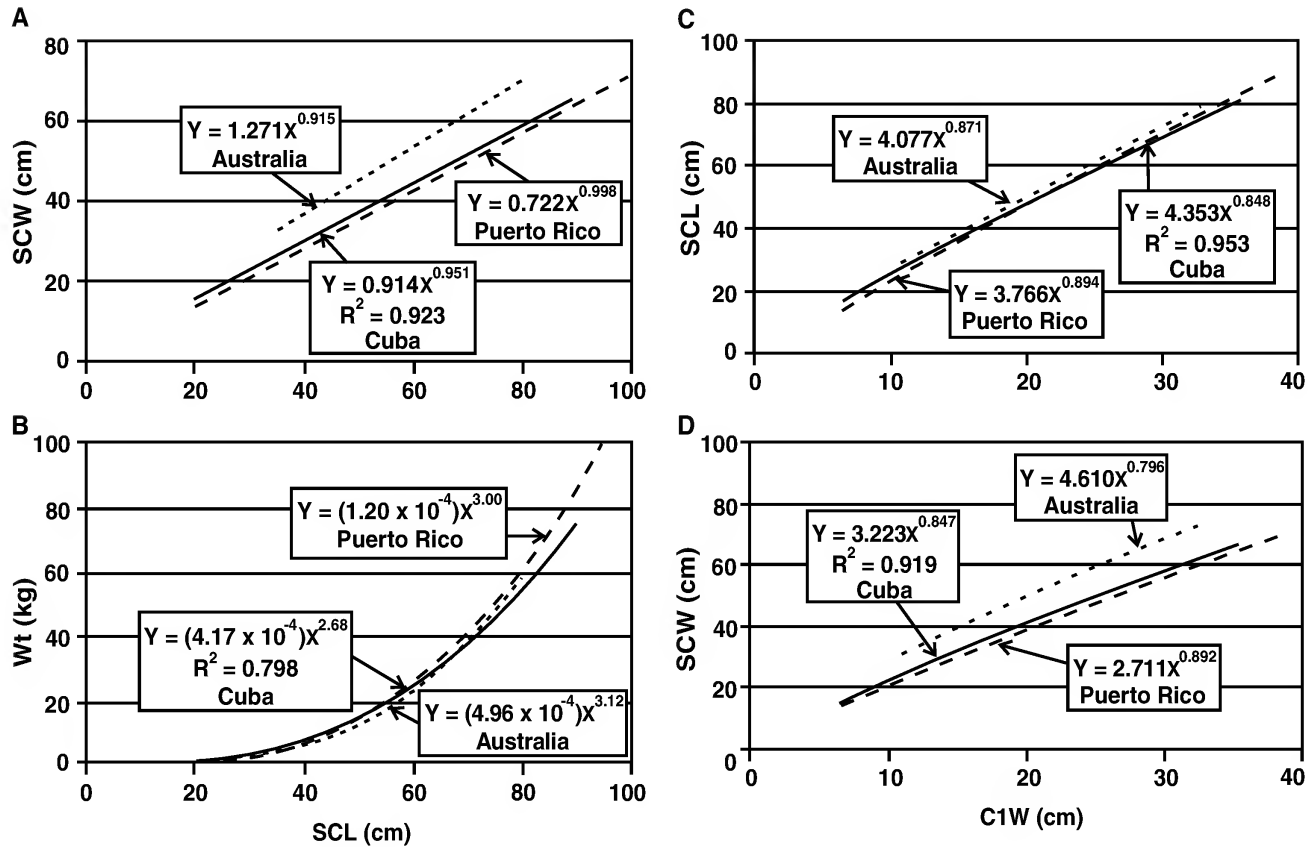
A

B

C

D

Figure 4. A) Plot of the relationships between straight carapace length (SCL) and straight carapace width (SCW). The solid line represents wild turtles from the Cuban waters, the dotted line represents a regression of Puerto Rican turtles (20 cm < SCL < 100 cm; van Dam and Diez 1998), and the shorter dotted line represents a regression of Australian turtles (28.5 cm < SCL < 86.6 cm; Limpus 1992). B) Plot of the relationship between SCL and weight (Wt). The solid line represents wild turtles from the Cuban waters, the dotted line represents Puerto Rican turtles (20 cm < SCL < 100 cm; van Dam and Diez 1998), and the shorter dotted line represents Australian turtles (28.5 cm < SCL < 86.6 cm; Limpus 1992). C) Plot of the relationship between the first costal width (C1W) and SCL. The solid line represents Cuban turtles, the dotted line represents Puerto Rican turtles (6.5 cm < C1W < 39.2 cm; van Dam and Diez 1998), and the shorter dotted represents Australian turtles (11.3 cm < C1W < 34.3 cm; Limpus 1992; Limpus and Miller 1990). D) Plot of the relationship between C1W and SCW. The solid line represents Cuban turtles, the dotted line represents Puerto Rican turtles (6.5 cm < C1W < 39.2 cm; van Dam and Diez 1998), and the shorter dotted line represents Australian turtles (11.3 cm < C1W < 34.3 cm; Limpus 1992; Limpus and Miller 1990).

words, I have revealed that there are similar growth rates of C1W and SCL. At the same time, my results show that measuring C1W is sufficient to speculate on SCL using the C1W-SCL relationship. For example, when a dead turtle's body part is missing or its scutes are the only parts available, we can extract data on the body size. Carapace 1 (C1) is very peculiar in shape and easily distinguishable from other scutes. Furthermore, because of the speckled pattern of the C1 that is more visible on C1 than on other scutes (Kobayashi 2001), it is very possible that C1 may provide information on age. Extracting physical data from one piece of scute on the carapace is very significant in terms of monitoring and making the most of precious information.

ACKNOWLEDGMENTS

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A New Species of *Protanaissus* Sieg, 1982 (Crustacea: Tanaidacea: Peracarida), from South Florida

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Recommended Citation

A NEW SPECIES OF *PROTANAISSUS* SIEG, 1982 (CRUSTACEA: TANAIDACEA: PERACARIDA), FROM SOUTH FLORIDA

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ABSTRACT A new nototanaid species, *Protanaissus floridensis,* is described from Biscayne Bay in southeastern Florida. Specimens were collected at a depth of 7 m in muddy sand substrata with associated aquatic vegetation (*Thalassia testudinum*). *Protanaissus floridensis,* which represents only the 4th species referable to the genus, is the first species of *Protanaissus* Sieg, 1982, known from the northern hemisphere. The new species is distinguished from the other 3 species of *Protanaissus* by 1) the dactylus of pereopod 1 shorter than combined length of propodus and carpus, 2) the dactylus of the cheliped with proximal spine on inner margin and proximal process on outer margin, 3) the fixed finger with 3–4 distal denticles on inner margin, and 4) the uropodal exopod uniarticulated. A key distinguishing the species of *Protanaissus* is presented.

INTRODUCTION

During a study of the tanaidacean fauna from near shore and shelf waters of Florida, a number of new species were discovered including one belonging to the genus *Protanaissus* Sieg, 1982. The description of this new nototanaid species is the subject of this report.

Protanaissus is a little known genus previously comprising only 3 species. *Protanaissus* is closely related to *Tanaissus* Norman and Scott, 1906, whose members are known from the eastern and western North Atlantic but *Protanaissus* differs in having unfused maxilliped endites. The habitat of both *Protanaissus* and *Tanaissus* is exposed coastal beaches or sandy bottom submitted to strong currents (Bird 2002, current report). The genus has so far been found only in shallow water.

The terminology follows that of Larsen (2003). Type material has been deposited in the National Museum of Natural History (USNM) and Gulf Coast Research Laboratory Museum (GCRL).

SYSTEMATICS

Tanaidomorpha Sieg, 1980
Nototanaididae Sieg, 1976
Protanaissus Sieg, 1982

Diagnosis. (Modified after Sieg, 1982). Female: Body elongated and cylindrical. Antennule with 3 articles. Antenna with 5–6 articles. Mandible outer margin square, giving an impression of a robust broad incisor; molar pointed and weakly chitinized or tapering into a small round crushing surface. Labium consisting of 1 pair of lobes without lateral and medial processes. Maxillule strongly curved, almost S-shaped. Maxilliped basis fused distally; endites not fused, narrower than basis and with 2 simple subdistal denticles. Chelipeds attached ventrally via sclerite. Pereopod 1–3 with small coxa. Pereopod 4-6 without coxa; dactylus and unguis shorter than propodus, fused to a claw. Pleopods present. Uropods biramous; endopod biarticulated; exopod with 1 or 2 articles.

Male: Unknown.

Protanaissus floridensis sp. nov. (Figures 1–3)

Material examined. Holotype (USNM 1019175): non-ovigerous female, body length 2 mm. Biscayne Bay, Miami Dade County. Florida. 25°63.4450'N. 80°21.8880'W. Depth 7 m. 11 July 2002. Bottom type: muddy sand/*Thalassia.* Benthic grab.

Paratype: 1 non-ovigerous female (GCRL 2057). Same locality.

Additional material. 1 juvenile female. Same locality.

Diagnosis. Female: Pereopod 1 dactylus shorter than combined length of propodus and carpus. Cheliped dactylus with proximal spine on inner margin and proximal process on outer margin. Fixed finger with distal denticles on inner margin. Uropod exopod uniarticulated.

Etymology. Named for the type locality in shallow waters off Florida, USA.

Description. Adult, non-ovigerous female

Body (Figures 1A, 1B). Elongated, almost 10 times longer than broad.

Cephalothorax. Longer than combined length of pereonite 1 and 2. Eye lobes present, but visual pigmentation weak and without identifiable ommatidia.

Pereonites. Pereonites 1, 2, and 6 wider than long. Pereonites 3 and 5 as wide as long. Pereonite 4 longer than wide.
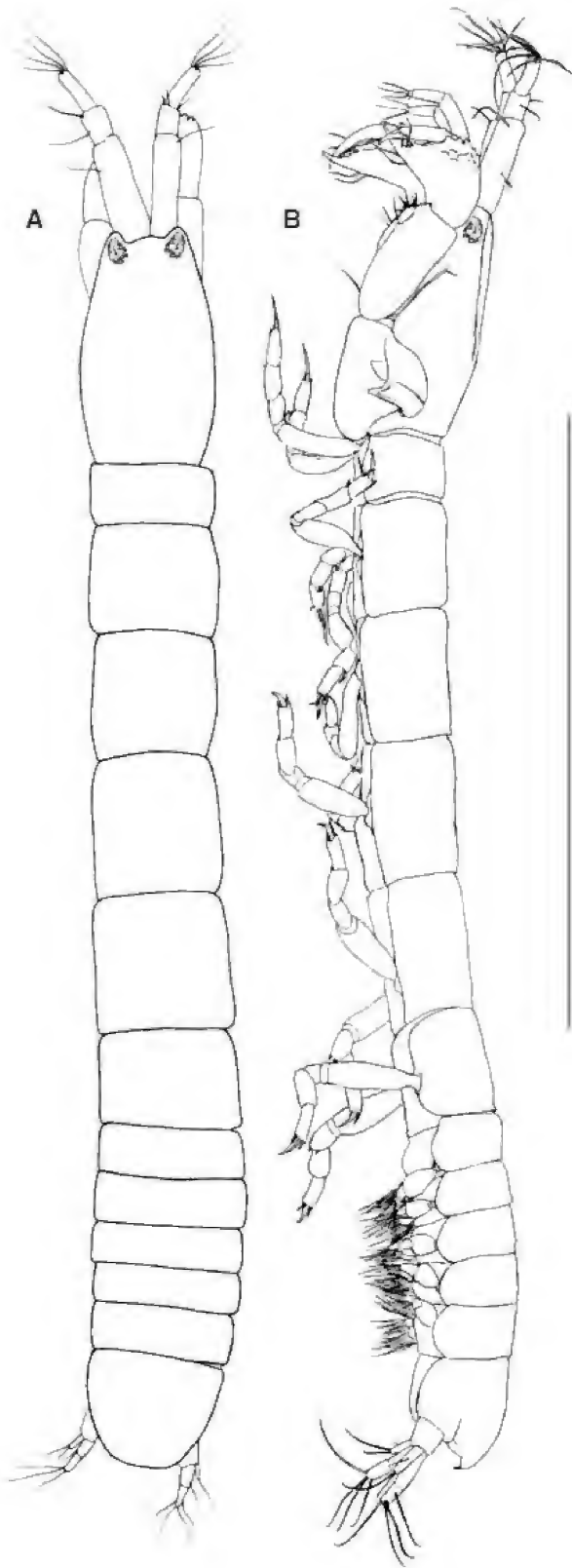
Figure 1. *Protanaissus floridensis,* **holotype, non-ovigerous female. A) Dorsal view. B) Lateral view. Scale bar 1 mm.**

Pleon. All pleonites subequal, as wide as pereon, all with pleopods. Pleotelson longer than combined length of 2 last pleonites, dorsally covered by a plate with pointed apex.

Antennule (Figure 2B). Shorter than cephalothorax. Article 1 longer than rest of antennule, with 1 simple medial and 5 distal setae. Article 2 shorter than article 3, with 1 simple and 1 sensory distal seta. Article 3 less than half the length of article 1, with 4 simple distal setae and 1 aesthetasc.

Antenna (Figure 2B). 0.8 times as long as antennule. Article 1 broader than following articles, naked. Article 2 shorter than article 1, with 1 simple distal seta. Article 3 longer than other articles, with 1 medial and 3 simple distal setae. Article 4 more than half as long as article 3, with 1 simple distal seta. Article 5 minute, with 4 simple distal setae.

Mouthparts. Labrum (Figure 2C) hood-shaped and naked. Right mandible not recovered. Left mandible (Figure 2D) molar process pointed, weakly chitinized and longer than incisor, with small distal depression. Incisor (Figure 2E) broad, with serrated upper margin. Lacinia mobilis pointing distally and with 2 denticles. Maxillule (Figure 2F) endite strongly bent, almost S-shaped, with 6 spiniform distal setae; palp shorter than endite; terminal setae shorter than palp. Maxilla (Figure 2F) ovoid. Labium not recovered. Maxilliped (Figure 2G) endites unfused, each with 2 simple subdistal setae. Basis fused distally; palp article 1 with outer margin longer than inner, naked; article 2 inner margin longer than outer, with 3 inner distal setae; article 3 elongate, with 3 inner distal setae; article 4 with 2 subdistal and 5 distal setae. Epignath not recovered.

Cheliped (Figure 2H). Basis divided unequally by sclerite, as long as carpus and twice as wide. Merus prominent, triangular, with 1 ventral seta. Carpus elongate, almost twice as long as wide, shorter than propodus inclusive of fixed finger, with 1 ventral seta. Propodus slender, with dorsal edge serrated distally, with 1 seta near dactylus insertion. Fixed finger with 2 ventral setae; 3 setae on inner margin, and with 3–4 distal denticles. Dactylus marginally longer than fixed finger, dorsally with long seta and prominent projection; inner margin with long seta-like spine.

Pereopod 1 (Figure 3A). Basis longer than 3 succeeding articles combined, naked. Ischium naked. Merus rounded, as long as carpus, naked. Carpus widening distally, shorter than propodus, naked. Propodus half the length of basis, with 2 simple distal setae and dorsal spine. Dactylus and unguis combined shorter than propodus.

Pereopod 2 (Figure 3B). As pereopod 1 except: merus and carpus with 1 spiniform ventral distal seta. Propodus shorter than on pereopod 1, with 1 spiniform distal seta.

Figure 2. *Protanaissus floridensis.* **A)** Sub-adult female, lateral view, scale bar 0.5 mm. **B–H from non-ovigerous adult female. B)** Antennule and antenna, scale bar 0.2 mm. **C)** Labrum, scale bar 0.05 mm. **D)** Left mandible, scale bar 0.05 mm. **E)** Left mandible, incisor, Scale bar 0.01 mm. **F)** Maxillule and maxilla, Scale bar 0.05 mm. **G)** Maxilliped, scale bar 0.05 mm. **H)** Cheliped, scale bar 0.2 mm.
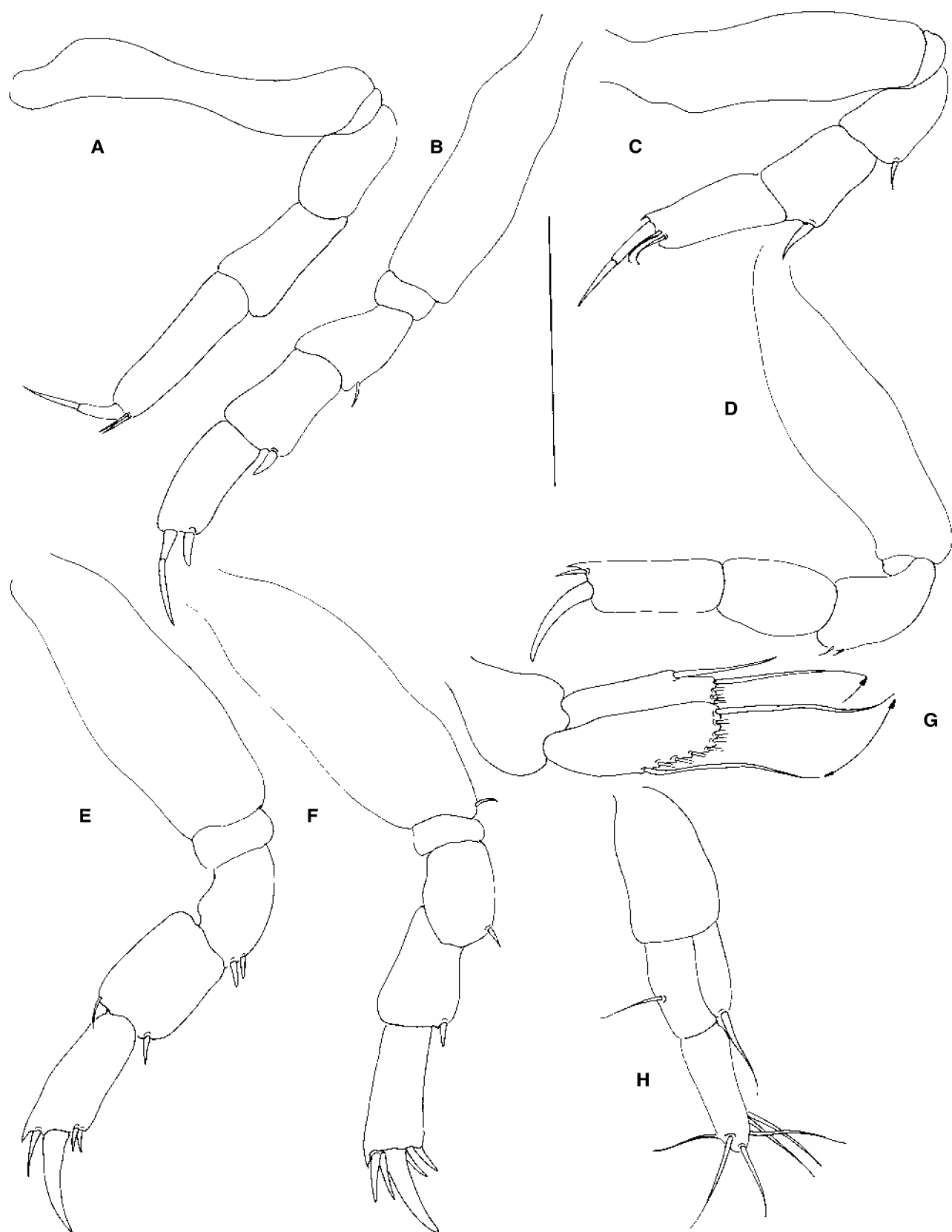
Figure 3. *Protanaissus floridensis,* **dissected non-type non-ovigerous adult female. A) Pereopod 1. B) Pereopod 2. C) Pereopod 3. D) Pereopod 4. E) Pereopod 5. F) Pereopod 6. G) Pleopod. H) Uropod. Scale bar 0.1 mm.**

Pereopod 3 (Figure 3C). As in pereopod 2 except: basis longer than 4 succeeding articles. Propodus with 2 curved distal setae.

Pereopod 4 (Figure 3D). Basis longer than 4 succeeding articles combined, naked. Ischium naked. Merus as long as carpus, with 2 simple ventral distal setae. Carpus naked. Propodus with 1 spiniform distal seta and dorsal spine. Dactylus and unguis fused into a claw.

Pereopod 5 (Figure 3E). As pereopod 4 except: merus with 2 spiniform ventral distal setae. Carpus square and with 2 distal setae. Propodus with 3 spiniform distal setae and dorsal spine.

Pereopod 6 (Figure 3F). Similar to pereopod 4 except: basis with 1 simple distal seta. Merus with 1 spiniform seta. Carpus with 1 spiniform distal seta. Propodus with 4 spiniform distal setae and dorsal spine.

Pleopod (Figure 3G). Basal article wider than rami. Exopod with 9 simple setae. Endopod with 5 outer and 1 inner simple setae.

Uropod (Figure 3H). Basal article more than half length of endopod, naked. Endopod with 2 articles, more than twice the length of exopod; first article with 1 medial seta; second article with 6 simple distal setae. Exopod with 1 simple distal seta.

Remarks. Some ontogenetic variations were noted between the adult and the sub-adult females. The pereonites are relatively more elongated and the pleopods more setose in the adult (Figures 1A, B) than in the sub-adult (Figure 2A). The pleotelson dorsal plate is also less pronounced in the sub-adult female than in the female.

Protanaissus floridensis occurs in the shallow shelf waters of South Florida, while *P. longidactylus* (Shiino, 1970) is only known from the Antarctic, *P. makrotrichos* Sieg, 1986, is found off the southern tip of South America, and *P. alvesi* Gutu, 1996 off the coast of Brazil. This distribution pattern suggests that additional species may occur along the Atlantic shelf of South America. The genus clearly has a eurythermal distribution. As with the other species of *Protanaissus*, *P. floridensis* is a rarely collected species. The species of *Protanaissus* are distinguished in the following key.

KEY TO THE SPECIES OF THE NOTOTANAIDID GENUS *PROTANAISSUS* SIEG, 1982.

1. Pereopod 1 dactylus shorter than combined length of propodus and carpus. Cheliped dactylus with proximal spine on inner margin and proximal process on outer margin. Fixed finger with at least 3 distal denticles on inner margin. Uropod exopod uniarticulated . . . . . *P. floridensis*

Pereopod 1 dactylus longer than combined length of propodus and carpus. Cheliped dactylus without proximal spine on inner margin or proximal process on outer margin. Fixed finger without multiple distal denticles on inner margin. Uropod exopod biarticulated 2

2. Mandibular molar pointed. Pereopod 6 propodus with 2 ventral simple setae of equal length . . . . . *P. longidactylus*

Mandibular molar tapering into a small crushing surface. Pereopod 6 propodus with 1 ventral seta shorter than propodus and 1 ventral seta more than twice the length of propodus 3

3. Antennule stout (article 1 length/width (l/w) ratio < 2). Pereon with 2 parallel black stripes (freshly collected material). Maxilliped palp article 2 with 1 robust setulose seta. . . . . *P. alvesi*

Antennule slender (article 1 l/w ratio 2.8). Pereon without black stripes. Maxilliped palp article 2 without robust setulose setae . . . . *P. makrotrichos*

DISCUSSION

Protanaissus was erected by Sieg (1982) to accommodate the species *Typhlotanais longidactylus* Shiino, 1970, which differs from the *Typhlotanais* generic definition in having a pointed and weakly chitinized mandibular molar, in contrast to the broad, heavily chitinized, molar which diagnose *Typhlotanais*. Shiino (1970:95) mentioned this but stated that many other characters resembled those of *Typhlotanais*. Sieg (1982:133) argued that the features of *T. longidactylus,* especially the shape of the molar and incisor, and the cheliped, point toward the genus *Tanaissus* Norman and Scott, 1909 within the Nototanaidae sensu Sieg, 1976 but that the unfused maxilliped endite of *T. longidactylus* warranted a new genus. Since Nototanaididae was erected as a family after the description of *T. longidactylus,* Shiino's (1970) reservations on the validity of the tanaidacean systematics were well founded and, as shown by Larsen and Wilson (2002), most of the genera previously belonging to Typhlotanaidae (*Typhlotanais, Peraeospinosus, Typhlotanoides,* and

Paratyphlotanais) come together as a monophyletic group within the redefined family Nototanaididae. However, Nototanaidae as a family is only supported by a very weak Bremer index and is thus not a very stable family.

Protanaissus were previously only known from 2 Antarctic species, *P. longidactylus* and *P. makrotrichos* Sieg, 1986, and one species from Brazil, *P. alvesi* Gutu, 1996. *Protanaissus floridensis* is the first species of this genus found in the northern hemisphere. All species of *Protanaissus* are only found in sandy habitats in high current exposed environments on the upper continental shelf.

ACKNOWLEDGMENTS

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Stomatopoda (Crustacea: Hoplocarida) from the Shallow, Inshore Waters of the Northern Gulf of Mexico (Apalachicola River, Florida to Port Aransas, Texas)

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STOMATOPODA (CRUSTACEA: HOPLOCARIDA) FROM THE SHALLOW, INSHORE WATERS OF THE NORTHERN GULF OF MEXICO (APALACHICOLA RIVER, FLORIDA TO PORT ARANSAS, TEXAS)

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ABSTRACT Six species representing the order Stomatopoda are reported from the shallow, inshore waters (passes, bays, and estuaries) of the northern Gulf of Mexico limited to a depth of 10 m or less, and by the Apalachicola River (Florida) in the east and Port Aransas (Texas) in the west. With the exception of the "live bottom" gonodactylid, *Neogonodactylus bredini* (Manning), these predatory crustaceans usually inhabit burrows in mud, sand-mud, and sand substrata in coastal and shelf waters. The species treated in this paper are *Neogonodactylus bredini* (Manning), *Lysiosquilla scabricauda* (Lamarck), *Bigelowina biminiensis* (Bigelow), *Coronis scolopendra* Latreille, *Squilla empusa* Say, and *Gibbesia neglecta* (Gibbes). The questionable record of *Squilla rugosa* Bigelow by Archer (1948) is discussed. A review of the life history, ecology, distribution, and new northern Gulf of Mexico records is provided here for each of these species. Figures and an illustrated key are also presented.

INTRODUCTION

Prior to the monograph by Manning (1969), stomatopod records for the Gulf of Mexico (GOM) were scattered throughout the literature. Manning consolidated much of that work and included new records in his materials. In a later work Camp (1973) reviewed the literature for the GOM taxa and added new distribution records for the Florida west coast. Thirteen species in 8 genera were listed and reviewed; yet, most of these records occurred in waters south of Cedar Key, Florida, and in depths greater than 10 m. More recent works on GOM Stomatopoda include material from southern Florida and consist mainly of records from deeper than 10 m; however, this group continues to be overlooked in the waters of the northern GOM.

Over the past several years, using yabby pumps, benthic dredges, and trawls, we have collected 6 species of Stomatopoda from northern GOM shallow, inshore marine and brackish-water habitats, less than 10 m in depth, between the Apalachicola River, Florida, and Port Aransas, Texas. New locality records are established for several of the species collected during our study. Synonyms are restricted to name changes; for full synonymies prior to 1968, refer to Manning (1969).

Museums mentioned in this paper are abbreviated as USNM (National Museum of National History, Smithsonian Institution, Washington, DC) and GCRL (The University of Southern Mississippi, Gulf Coast Research Laboratory, Ocean Springs, Mississippi). Total length (TL) and carapace length (CL) were measured in millimeters (mm) according to Manning (1969).

AN ARTIFICIAL KEY TO THE STOMATOPODA (CRUSTACEA: HOPLOCARIDA) FROM THE SHALLOW, INSHORE WATERS OF THE NORTHERN GOM

1a. Telson without sharp median carina; median carina, if present, inflated or broadly rounded (Figures 1a–e) 2

1b. Telson with sharp median carina (Figures 2a–b) (Superfamily Squilloidea). 5

2a. Dactylus of raptorial claw unarmed (Figure 3a); propodi of 3rd and 4th maxillipeds slender, not beaded or ribbed ventrally (Figure 3b); telson with accessory median carinae present (Figures 3c–d) . . . . . *Neogonodactylus bredini*

2b. Dactylus of raptorial claw armed with 6 or more teeth (Figures 4a,d); propodi of 3rd and 4th maxillipeds broad, beaded, or ribbed ventrally (Figure 4b); telson with accessory median carinae absent (Figures 4c, e–f) (Superfamily Lysiosquilloidea). 3

3a. First 2 walking legs with endopod having distal segment elongate (Figure 5a); uropod having endopod with proximal part of outer margin not folded (Figure 5b) (Family Lysiosquillidae) . . . . . . *Lysiosquilla scabricauda*

3b. First 2 walking legs with endopod having distal segment ovate or subcircular (Figure 6a); uropod having endopod with proximal part of outer margin folded dorsally onto itself (Figures 6b–c) (Family Nannosquillidae). . 4

4a. Telson, dorsal surface with 5 or more spines in fan-shaped series (Figure 7c) . . . . *Bigelowina biminiensis*

4b. Telson, dorsal surface unarmed (Figure 8d). . . . . *Coronis scolopendra*
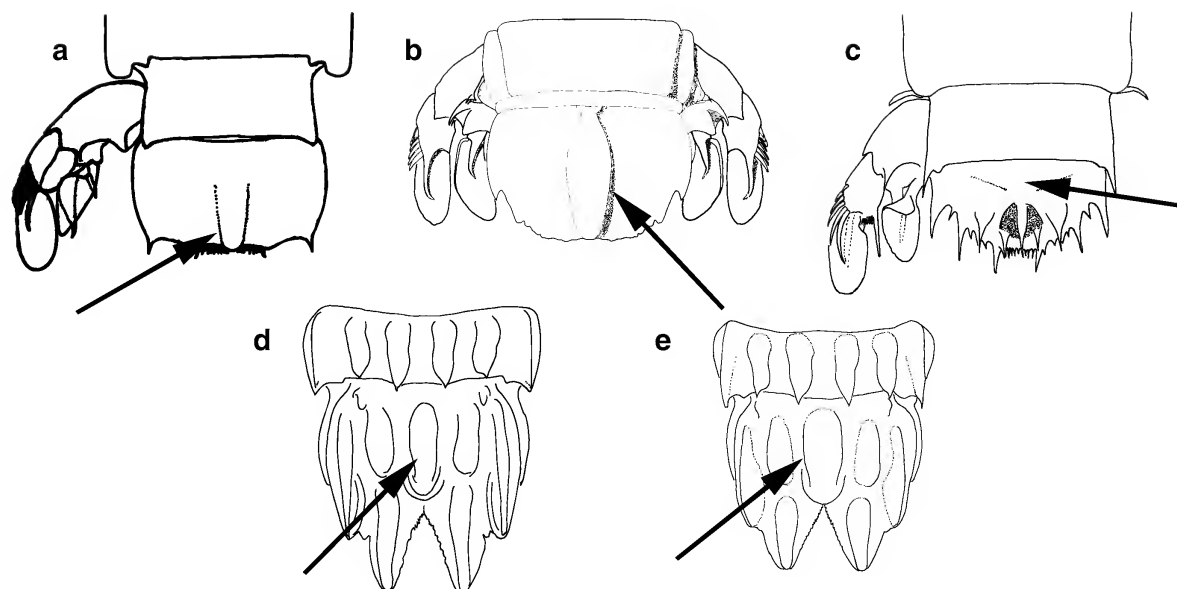
Figure 1. a) *Coronis scolopendra* Latreille, 1828, last abdominal somite, telson, and uropod (arrow indicates slight median carina). b) *Lysiosquilla scabricauda* (Lamarck, 1818), last abdominal somite, telson, and uropods (arrow indicates slight median carina). c) *Bigelowina biminiensis* (Bigelow, 1893), last abdominal somite, telson, and uropod (arrow indicates slight median carina). d–e) *Neogonodactylus bredini* (Manning, 1969). d) male last abdominal somite and telson (arrow indicates broad, rounded median carina). e) female last abdominal somite and telson (arrow indicates broad, rounded median carina); (setae omitted for clarity) (a, redrawn from Manning 1969: Figure 24b; c, redrawn from Manning 1969: Figure 15c; d, redrawn from Manning 1969: Figure 87b; e, redrawn from Manning 1969: Figure 88b).

5a. Fifth thoracic somite with lateral process produced as a spatulate process, not a sharp spine (Figure 9c); dactylus of raptorial claw with 5 teeth (Figure 9e); mandible without palp (not shown) . . . . *Gibbesia neglecta*

5b. Fifth thoracic somite with lateral process produced as a sharp spine, not spatulate (Figure 10c); dactylus of raptorial claw with 6 teeth (Figure 10e); mandible with palp (not shown) . . . . *Squilla empusa*

SYSTEMATIC ACCOUNT

Class Malacostraca Latreille, 1802
Subclass Hoplocarida Calman, 1904
Order Stomatopoda Latreille, 1817
Suborder Unipeltata Latreille, 1825
Superfamily Gonodactyloidea Giesbrecht, 1910
Family Gonodactylidae Giesbrecht, 1910
Neogonodactylus bredini **(Manning, 1969)**
(Figures 1d–e, 3a–d)

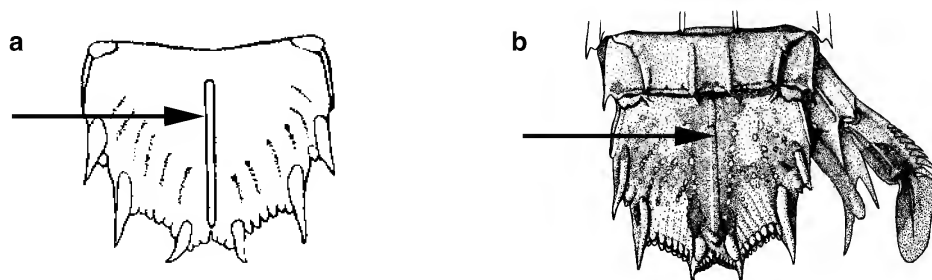**Synonyms.** *Gonodactylus bredini* Manning 1969: 315; *Neogonodactylus bredini* Manning 1995: 80.

Figure 2. a) *Gibbesia neglecta* (Gibbes, 1850), telson (arrow indicates sharp median carina). b) *Squilla empusa* Say, 1818, last abdominal somite, uropod, and telson (arrow indicates sharp median carina); (setae omitted for clarity) (a, modified from Camp 1973: Figure 13; b, from Manning 1969: Figure 58e).
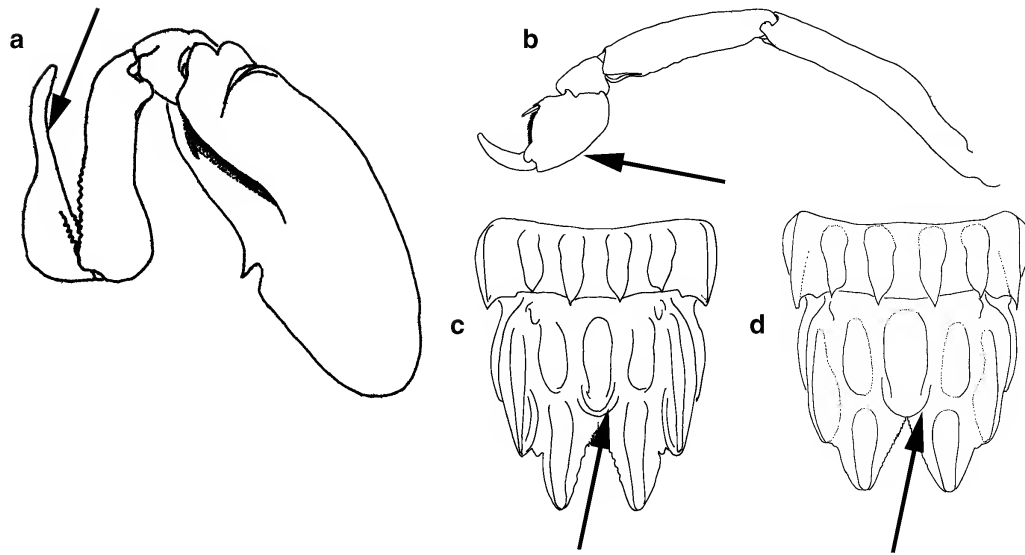
50

Figure 3. a–b) *Neogonodactylus bredini* (Manning, 1969). a) right, raptorial claw, inner view (arrow indicates dactylus without teeth). b) right third maxilliped (arrow indicates slender propodus, lacking beads or ribs on ventral surface). c) male last abdominal somite and telson (arrow indicates accessory median carina). d) female last abdominal somite and telson (arrow indicates accessory median carina); (setae omitted for clarity) (c, redrawn from Manning 1969: Figure 87b. d) redrawn from Manning 1969: Figure 88b).

Diagnosis. Rostral plate with basal portion much broader than long, long apical spine present. Cornea subcylindrical; ocular scales narrow, longer than wide. Mandible with palp present. Raptorial claw with dactylus unarmed. First and second abdominal somites with posterior margins evenly concave. Third and 4th abdominal somites with posterior margin of pleura straight to slightly concave. Fifth abdominal somite with posterolateral margins rounded or angled slightly, lateral margins unarmed. Sixth abdominal somite with 6 variously sized carinae, submedian and intermediate carinae often with apices unarmed. Telson usually slightly broader than long; dorsal surface unarmed; median carina often inflated, armed at most with apical tubercle; short accessory carina present, occasionally inflated, often fused posteriorly; lateral tooth not produced into a spine; submedian carina at most longitudinally pitted, never sulcate; intermediate carina with accessory carina medially. Uropod with endopod broad, inner margin straight to slightly convex, occasionally faintly sinuous, not strongly tapering towards apex.

Distribution. Western Atlantic, from Bermuda, the Carolinas, and the northern GOM through the Caribbean to Aruba, Bonaire, and Curaçao off the coast of South America (Manning 1969).

New Northern GOM Records. Adult, TL 55 mm, CL 16 mm, West Pass jetties, St. Andrew Bay, Florida, 27 July 1995, 1.0 m, rock wash, coll. J.M. Foster, id. by J.M. Foster, GCRL 2055.

Habitat. In sponges, on rocks, and among corals from the littoral zone to 15 m (Manning 1969).

Remarks. Closely related to *N. oerstedii* Hansen, 1895, *N. bredini* was distinguished as a distinct species by Manning (1969) and was transferred from the genus *Gonodactylus* to the newly erected genus *Neogonodactylus* by Manning (1995), based largely upon the morphology of carinae of the telson. Members of the genus *Neogonodactylus* are distinguished by having an accessory carina located medial to the intermediate carina.

Manning and Heard (1997) differentiated the new species *N. wennerae* from *N. bredini* based upon habitat, size, and the morphology of the rostrum; however, recent molecular work has shown that the distinction between *N. bredini* and *N. wennerae* is confused at best (Paul Barber, pers. comm., Boston University, Boston, MA). Preliminary results have shown *N. bredini* to be a Caribbean species whereas *N. wennerae* appears to be a northern species, being distributed in Bermuda, the Carolinas, Georgia, parts of Florida and possibly the GOM. Depth does not seem to be a factor in separating the 2 species as previously believed. When these 2 species are eventually separated by molecular means, it is possible that morphological characters will be identified. Based upon current literature, the specimen collected at the West Past jetties is referred to *N. bredini*; however, current molecular studies of this species complex may reveal this specimen to be *N. wennerae*.

Although numerous records for *N. bredini* exist for the GOM, primarily from the results of cruises of the *Albatross* (1884–1887), the *Fish Hawk* (1880–1916), the *Pelican* (1938–1940), the *Oregon* (1950–1964), and the *Hernan Cortez* (1965–1967) (Manning 1969, Camp 1973),
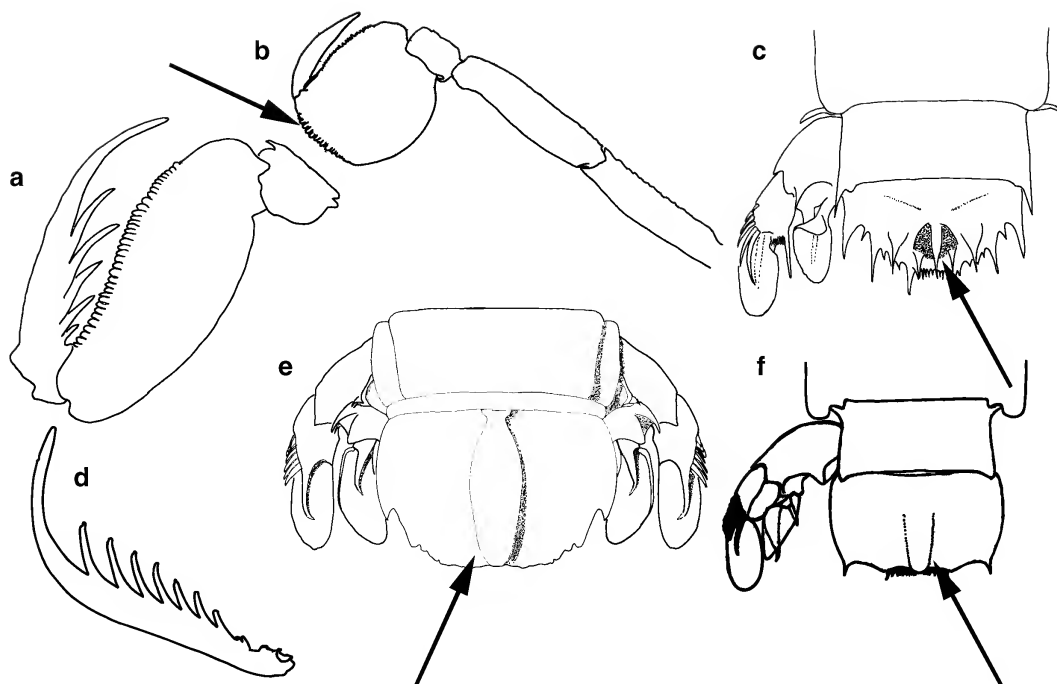
Figure 4. a–c) *Bigelowina biminiensis* (Bigelow, 1893). a) raptorial claw. b) right third maxilliped (arrow indicates beaded ventral margin of propodus). c) last abdominal somite, telson, and uropod (arrow indicates that accessory median carina is lacking). d–e) *Lysiosquilla scabricauda* (Lamarck, 1818). d) dactylus of raptorial claw. e) last abdominal somite, telson, and uropods (arrow indicates accessory median carina lacking). f) *Coronis scolopendra* Latrielle, 1828, last abdominal somite, telson, and uropod (arrow indicates accessory median carina is lacking); (setae omitted for clarity) (a, redrawn from Manning 1969: Figure 15b; c, redrawn from Manning 1969: Figure 15c; d, from Camp 1973: Figure 2; f, redrawn from Manning 1969: Figure 24b).

the occurrence of an adult specimen at the rock jetties at the mouth of St. Andrew Bay represents the northern-most record for *N. bredini* in the GOM. Whereas the specimen collected on the West Pass jetties was from a depth of about 1 m, most of the previous records for the GOM are from depths of over 10 m. Based upon its habitat and distribution in the southern part of its range, this species may occur widely on hard and live bottom substrata in the shallow waters of the northeastern GOM.

Superfamily Lysiosquilloidea Giesbrecht, 1910
Family Lysiosquillidae Giesbrecht, 1910
Lysiosquilla scabricauda **(Lamarck, 1818)**
(Figures 1b, 4d–e, 5a–b)

Synonyms. *Squilla scabricauda* Lamarck 1818: 188; *Lysiosquilla scabricauda*—Miers 1880: 7.

Diagnosis. Eyes very large; cornea bilobed; ocular scales triangular, separate, apices acute, inclined anterior-
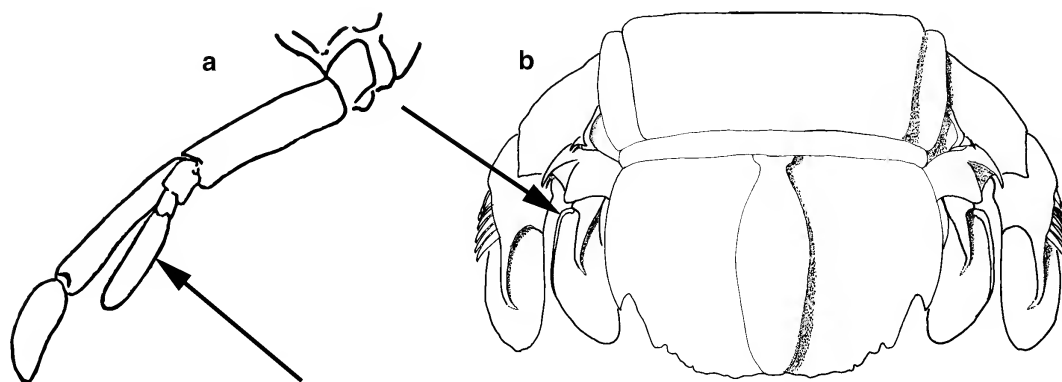

Figure 5. a–b) *Lysiosquilla scabricauda* (Lamarck, 1818). a) first walking leg (arrow indicates elongate endopod). b) last abdominal somite, telson, and uropods (arrow indicates endopod lacking dorsal fold); (setae omitted for clarity).
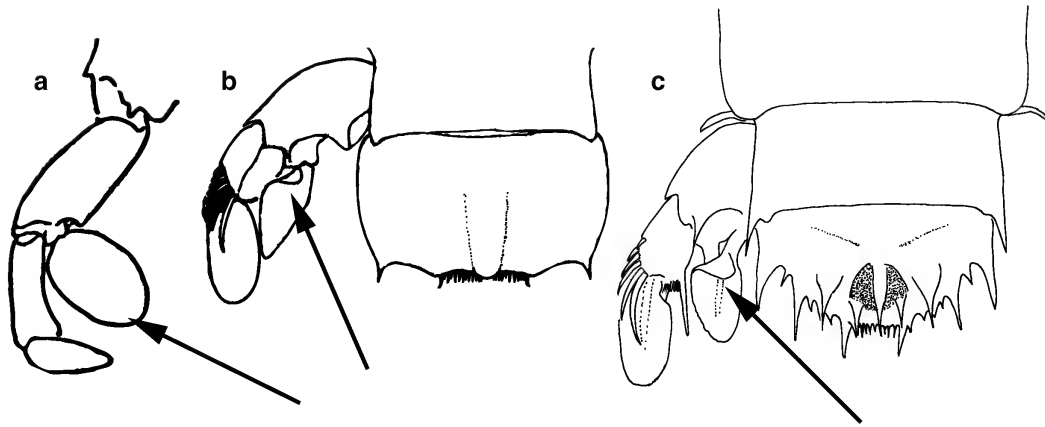
Figure 6. a–b) *Coronis scolopendra* Latreille, 1828. a) first walking leg (arrow indicates ovate endopod). b) last abdominal somite, telson, and uropod (arrow indicates endopod of uropod with outer margin folded dorsally). c) *Bigelowina biminiensis* (Bigelow, 1893), last abdominal somite, telson, and uropod (arrow indicates endopod of uropod with outer margin folded dorsally); (setae omitted for clarity) (b, redrawn from Manning 1969: Figure 24b; c, redrawn from Manning 1969: Figure 15c).

ly. Antennule with peduncle short, little more than half length of carapace; antennular processes produced into broad, anteriorly directed spines. Raptorial claw with dactylus having 8 to 11 teeth, typically 9 to 10. Eighth thoracic somite having high ventral keel with posterior apex rounded or sharp. Fourth abdominal somite with dorsal surface smooth; lateral margins unarmed. Fifth abdominal somite with dorsal surface smooth, slightly wrinkled laterally; posterior margin with spinules, diminishing medially. Sixth abdominal somite with dorsal surface roughened; triangular spine in front of articulation of uropod. Telson rectangular to ovate, broader than long; dorsal surface irregularly roughened with minute tubercles, tubercles increasing in size and density near lateral margins; lateral margins smooth or with series of small spinules; median carina broad and rounded. Uropod with endopod elongate, 2.5 times wide as long, proximal portion of endopod not folded over dorsal surface of endopod.

Distribution. In the western Atlantic, from Bermuda, the Bahamas, South Carolina, and the GOM through the Caribbean to southern Brazil, sublittoral to 55 m (Manning 1969, Camp 1973).

New Northern GOM Records. Adult, Grand Lagoon, St. Andrew Bay, Florida, June, 1977, 2 m, muddy sand substrata, hook and line, coll. J.M. Foster, id. by J.M. Foster, personal collection of author (JMF); subadult, northwestern tip of Horn Island, Mississippi Sound, Mississippi, subtidal coarse sand substratum, May 1989, 1.5 m, coll. R.W. Heard, id. by R.W. Heard, personal collection of author (RWH); Adult, Dog Keys Pass, Mississippi Sound, on R/V *Hermes*, 2 August 1968, 5.0 m, id. by C.E. Dawson, GCRL 881.

Habitat. Burrows in sand, emerging from burrows at night, possibly for feeding (Manning 1969).

Remarks. This species, which attains a maximum TL of 275 mm, represents the largest western Atlantic species of stomatopod and is widely distributed.

Family Nannosquillidae Manning, 1980
Bigelowina biminiensis (Bigelow, 1893)
(Figures 1c, 4a–c, 6c, 7a–d)

Synonyms. *Lysiosquilla biminiensis* Bigelow 1893: 102; *Acanthosquilla biminiensis*—Manning 1963: 320; *Bigelowina biminiensis* Schotte and Manning 1993: 574.

Diagnosis. Rostral plate rectangular, with single apical spine. Eyes very small; cornea subglobular. Antennule having peduncle short, less than half as long as carapace; antennular processes produced as sharp, anteriorly directed spines when viewed laterally. Mandible with palp present; 5 epipods present. Raptorial claw with dactylus having 6 to 7 teeth. Telson twice as broad as long; dorsal surface having 5 subequal teeth; no sharp median carina; 4 to 5 submedian denticles, outer largest, inner smallest; 4 denticles between movable submedian tooth and next fixed tooth. Uropod having endopod with proximal portion folded over dorsal surface.

Distribution. Bimini, Bahamas; eastern and northern GOM; Texas (Sabine Pass); Cuba; Brazil (Manning 1969).

New Northern GOM Records. West Pass, St Andrew Bay, Florida, 13 October 1990, 1.0 m, sand substrata, coll. J.M. Foster, id. by R.B. Manning, USNM 268895; adult, TL 55 mm, CL 14 mm, southwest tip of Horn Island, Mississippi, 9 March 2000, 1.5 m, sand substrata, coll. R.W. Heard, id. by R.W. Heard, GCRL 2056.
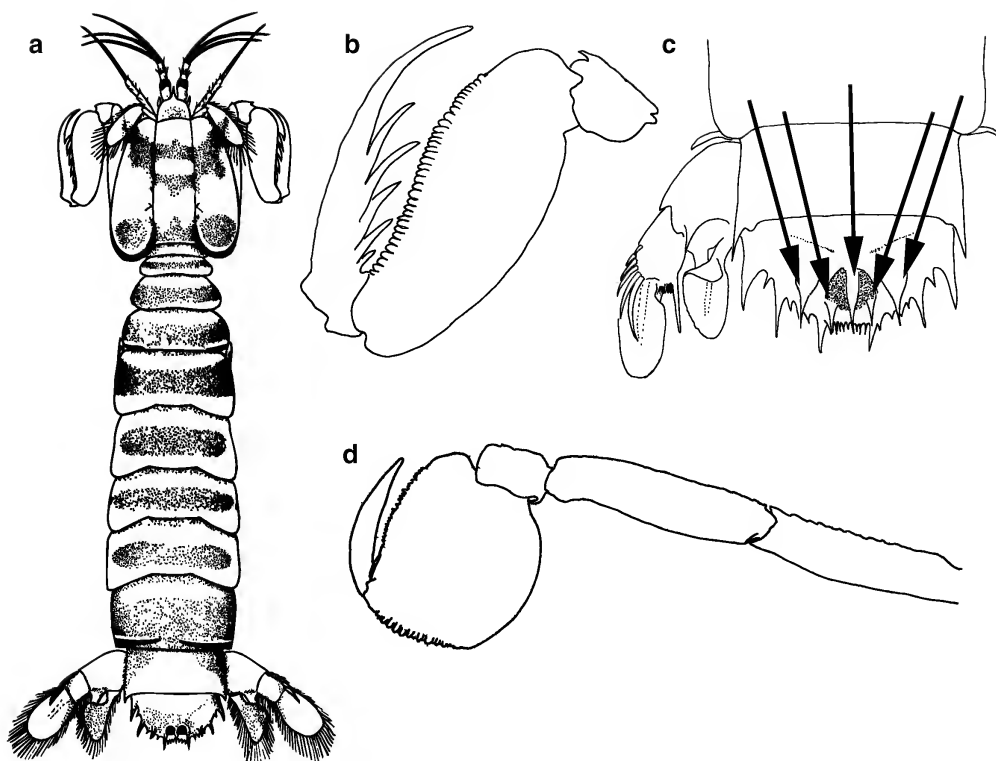
Figure 7. a–d) *Bigelowina biminiensis* (Bigelow, 1893). a) dorsal view. b) raptorial claw. c) last abdominal somite, telson, and uropod (arrows indicate 5 dorsal spines). d) right third maxilliped; (setae omitted for clarity) (a, from Manning 1969: Figure 14; b, redrawn from Manning 1969: Figure 15b; c, redrawn from Manning 1969: Figure 15c).

Habitat. Burrows in sand, sublittoral to 24 m (Manning 1969)

Remarks. *Bigelowina biminiensis* was transferred from the genus *Acanthosquilla* by Schotte and Manning (1993) based largely upon the morphology of the rostral plate and the shape of the cornea. The rostral plate, which is triangular in *Acanthosquilla* sensu stricto, is rectangular in members of the genus *Bigelowina*. Also, in members of *Bigelowina*, the cornea is subglobular, whereas that of *Acanthosquilla* is bilobed.

Coronis scolopendra Latreille, 1828
(Figures 1a, 4f, 6a–b, 8a–d)

Synonyms. *Coronis scolopendra* Latreille 1828: 474; *Lysiosquilla excavatrix* Brooks 1886: 10; *Coronis excavatrix* Lunz 1935: 153.

Diagnosis. Rostral plate as broad as or slightly broader than long; lateral margins broadly rounded; single apical spine present. Eyes very small; cornea subglobular; ocular scales fused. Antennule having peduncle less than half as long as carapace; antennular processes as sharp, anteriorly directed spines on either side of rostral plate.

Raptorial claw with dactylus having 13 to 17 teeth. Telson much broader than long; dorsal surface smooth; median carina broadly rounded; row of 8 to 21 denticles along median of posterior margin; single submedian tooth and single sharp lateral tooth present on either side of telson. Uropod having endopod with proximal portion folded over dorsal surface.

Distribution. Intermittent between North Carolina and Brazil (see Rodrigues and Manning 1992).

New Northern GOM Records. Adult, TL 54 mm, CL 13 mm, West Pass jetties, St. Andrew Bay, Florida, 13 October 1990, 1.0 m, subtidal sand, yabby pump, coll. J.M. Foster, id. by J.M. Foster, GCRL 2058; adult, TL 71 mm, CL 13 mm, Bid-a-wee Beach, Panama City Beach, Florida, subtidal on sand bars, 2 May 1995, 1.0–1.5 m, coll. J.M. Foster, id. by J.M. Foster, GCRL 2059; 1 adult, TL 66 mm, CL 12 mm, 3 subadults, TL 27 mm, CL 6 mm, TL 30 mm, CL 6 mm, TL 34 mm, CL 7 mm, Bid-a-wee Beach, Panama City Beach, Florida, 10 May 2000, 1.5 m, coll. G.O. Faust, id. by R.W. Heard, GCRL 2060; Horn Island, 100 m offshore, 1.0 m, 14 June 1952, coll. H.J Bennett, id. by C.E. Dawson, GCRL 628 (as *Lysiosquilla excavatrix* (Brooks, 1886)); juvenile, west end of Horn
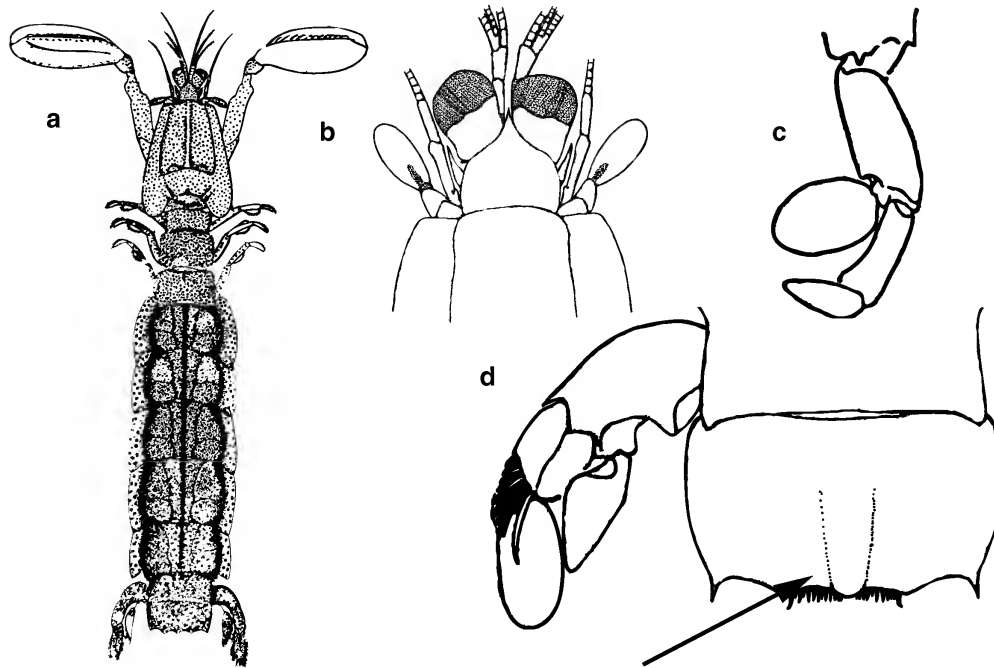
Figure 8. a–d) *Coronis scolopendra* Latrielle, 1828. a) dorsal view. b) anterior portion of body. c) first walking leg. d) last abdominal somite, telson, and uropod (arrow indicates dorsal surface of telson lacking spines); (setae omitted for clarity) (a, from Manning 1969: Figure 23; b, redrawn from Manning 1969: Figure 24a; d, redrawn from Manning 1969: Figure 24b).

Island, Mississippi Sound, Mississippi, 10 April 1968, less than 1.0 m, coll. D. Farrell, id. by C.E. Dawson, GCRL 840 (as *Lysiosquilla excavatrix* (Brooks, 1886)).

Habitat. Clean sand substrata in shallow water adjacent to beaches.

Remarks. Manning and Reaka (1989) determined that *C. scolopendra* Latreille, 1828, is the senior synonym of *C. excavatrix* Brooks, 1886. This interesting stomatopod is relatively common on coarse sand bottoms on both the north and south sides of the barrier islands of the northeastern GOM. Its burrows, which often have more than one opening, can reach depths of over 25 cm. According to R.B. Manning (pers. comm.), *C. scolopendra* preys on small fishes. The males and females of *C. scolopendra* exhibit sexual dimorphism, with adult females being dark blackish-brown and adult males pale translucent yellow (Heard, pers. obs.). Specimens are relatively easy to collect using a yabby pump. For additional information see Pearse et al. (1942), Manning (1969), Manning and Reaka (1989), Rodrigues and Manning (1992), and Manning and Heard (1997).

Superfamily Squilloidea Latreille, 1802
Family Squillidae Latreille, 1802
Squilla empusa **Say, 1818**
(Figures 2b, 10a–e)

Synonyms. *Squilla empusa* Say 1818: 250.

Diagnosis. Rostral plate subquadrate, broader than long; distinct median carina present; apical spine absent. Eyes large; cornea bilobed; ocular scales separated, rounded or obtusely angled laterally. Antennule with peduncle as long as carapace or nearly so; antennular processes tapering to blunt, anterolaterally directed spines. Mandible with palp present; 5 epipods present. Raptorial claw with dactylus having 6 teeth; carpus with dorsal ridge having 2 to 3 irregular tubercles. Carapace with dorsal surface minutely punctate; anterolateral spines strong, extending to or slightly beyond base of rostral plate; posterolateral margins angled anteriorly; strong carinae prominent, median carina, anterior to cervical groove, bifurcate anteriorly only. Telson as broad as long, sharp marginal spines present; prelateral lobes present; median carina sharp; denticles rounded; single lateral marginal tooth per side; 6 to 9 intermediate marginal teeth per side; 3 to 5 submedian marginal teeth per side.

Distribution. Western Atlantic from Maine through the GOM to Surinam (Manning 1969).

New Northern GOM Records. Adult, TL 142 mm, CL 37 mm, Sulfur Point, St Andrew Bay, Florida, 5 May
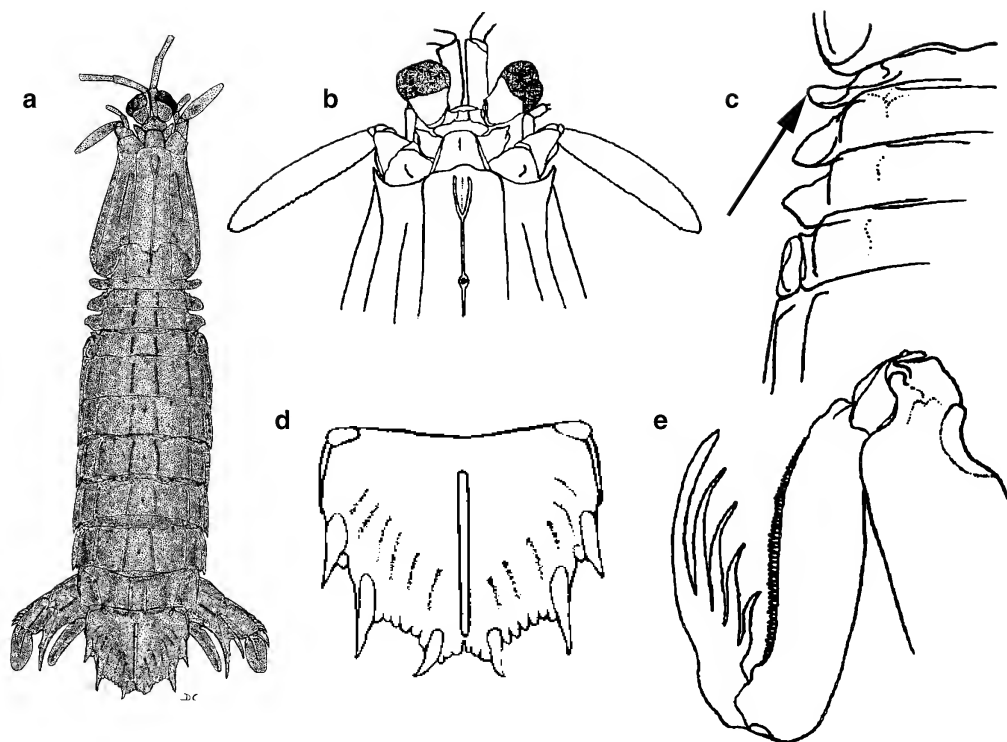
Figure 9. a–e) *Gibbesia neglecta* (Gibbes, 1850). a) dorsal view. b) anterior portion of body. c) lateral processes of 5th to 7th thoracic somites (arrow indicates spatulate 5th lateral process). d) telson. e) raptorial claw (note 5 teeth on dactylus); (setae omitted for clarity) (a, from Camp, 1973: Figure 13; b, from Manning and Heard, 1997: Figure 14a; c, from Manning and Heard, 1997: Figure 14c; d, modified from Camp, 1973: Figure 13; e, from Manning and Heard, 1997: Figure 14b).

1977, 8.0 m, mud substrata, trawl, coll. J.M. Foster, id. by J.M. Foster, GCRL 2061; south of Grand Isle, Louisiana, 4 November 1959, 20 m, coll. C.E. Dawson, id. by C.E. Dawson, GCRL 363; northwest of Horn Island, Mississippi Sound, Mississippi, 22 July 1951, 6.0 m, coll. H. Hefley, id. by F.A. Chace, GCRL 542.

Habitat. Burrows in sand or mud sediments, 0-154 m (Manning 1969).

Remarks. This is the most common large stomatopod in the near shore coastal waters of the northern GOM. It is commonly caught in trawls on sand-mud or mud bottoms around Ship and Horn Islands, Mississippi. This mantis shrimp has been found in the stomachs of Cobia (*Rachycentron canadum*) caught in Mississippi waters (G. Meyer, unpub. data). Manning (1969) has summarized the biological information on this well-known mantis shrimp.

The single record of *Squilla rugosa* Bigelow, 1893, as *Chloridella rugosa* sensu Rathbun, 1899, in Archer (1948) is questionable. This species is common in deeper waters, but outside of the record by Archer (1948), it has not been recorded in the shallow waters of the north central GOM. It seems likely that the specimens collected during Archer's survey were actually *S. empusa*, which is a com-

mon species in the Mississippi Sound. *Squilla rugosa* can be separated from *S. empusa* by the rugose dorsal surface of the telson. Without access to the specimens Archer examined, it is impossible to be certain of their identity.

Gibbesia neglecta (Gibbes, 1850)
(Figures 2a, 9a–e)

Synonyms. *Squilla neglecta* Gibbes 1850: 200; *Gibbesia neglecta* - Manning and Heard 1997: 313.

Diagnosis. Rostral plate truncate, broader than long, having apex transverse, not rounded; rostral spine absent; distinct median carina present. Eyes large; cornea bilobed; ocular scales separate, truncate. Antennule having peduncle shorter than carapace; antennular processes with margins sinuous, apex blunt, spine absent. Mandible with palp absent; 5 epipods present. Raptorial claw with dactylus having 5 teeth. Carapace with dorsal surface roughened; strong carinae present, median carina, anterior to cervical groove, bifurcate at both ends. First through 4th abdominal somites having 4 pairs of carinae, median carina absent. Telson dorsoventrally compressed, about as long as broad; median carina very sharp with long apical spine; sharp
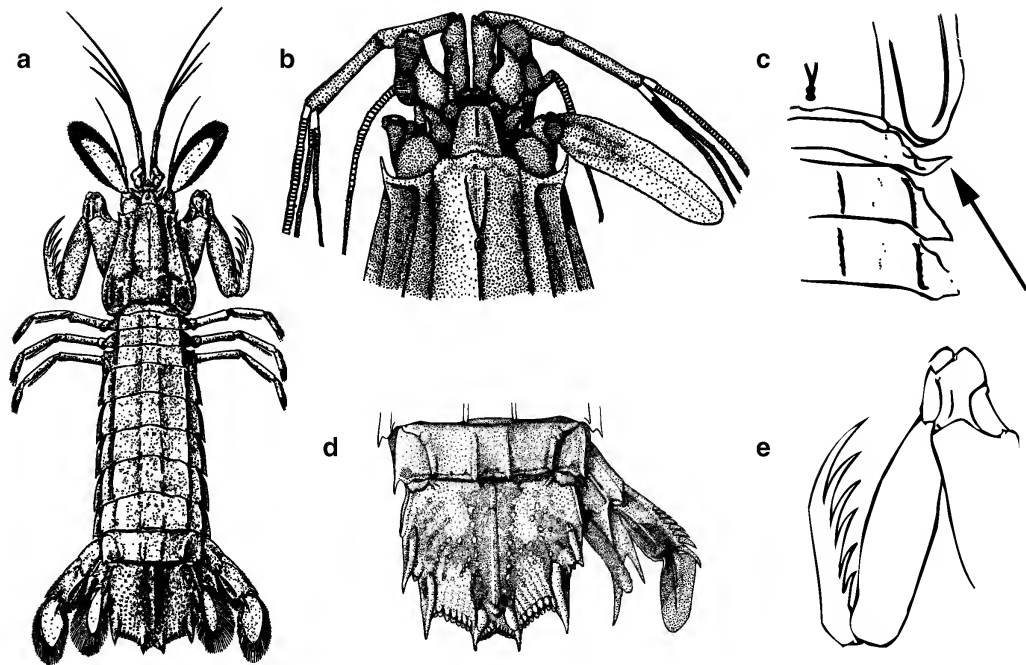
Figure 10. a–e) *Squilla empusa* Say, 1818. a) dorsal view. b) anterior portion of body. c) lateral processes of 5th to 7th somites (arrow indicates sharp 5th lateral process). d) last abdominal somite, uropod, and telson. e) raptorial claw (note 6 teeth on dactylus); (setae omitted for clarity) (a, from Rathbun, 1893: pl. 274; b, from Manning, 1969: Figure 58a; c, from Manning, 1969: Figure 58d; d, from Manning, 1969: Figure 58e; e, modified from Manning, 1969: Figure 59).

marginal teeth present; 2 to 4 submedian denticles, apices fixed; 5 to 7 intermediate denticles present.

Distribution. Atlantic coast of the United States, in the Carolinas, Georgia, and northeastern Florida. In the GOM on the western and northwestern coast of Florida, and on Texas coast (Manning 1969).

New Northern GOM Records. ca. 1 mile NE of Ship Island, Mississippi Sound, Mississippi, 5 February 1973, mud substrata, coll. R.W. Heard, id. by R.W. Heard, GCRL 1064.

Habitat. Littoral zone to 64 m (Manning 1969); mud and mud-sand substrata in bays and near coastal waters, mesohaline to polyhaline.

Remarks. This species is distinguished from *S. empusa* by having 5 teeth on the dactylus of the raptorial claw instead of 6; and by having a spatulate lateral process on the 5th thoracic somite rather than a spine-like process as in *S. empusa*.

Manning and Heard (1997) recently transferred this species from the genus *Squilla* Latreille, 1802 to the monotypic genus *Gibbesia* Manning and Heard, 1997. This species appears to be much less common than *S. empusa* in the coastal waters of the northern GOM. The single adult specimen collected by RWH at the northern entrance of Dog Keys Pass (NE of Ship Island) during 1973 constitutes the first record of this species in Mississippi coastal waters.

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ARTIFICIAL REEF MATRIX STRUCTURES (ARMS): AN INEXPENSIVE AND EFFECTIVE METHOD FOR COLLECTING CORAL REEF-ASSOCIATED INVERTEBRATES

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ABSTRACT Collecting reef-associated invertebrates usually involves disturbance of the reef area, often damaging the habitat and sometimes damaging live corals. We introduce a nondestructive, inexpensive, and effective method for collecting coral reef-associated invertebrates using approximations of small coral heads constructed of concrete, PVC pipes, nylon cleaning pads, and other materials easily obtainable in most tropical (coral-rich) countries. An example showing the effectiveness of the method is presented based on fieldwork in the eastern Caribbean.

INTRODUCTION

Coral reefs are well known as areas of extremely high biodiversity (e.g., Sheppard 1980, Huston 1985, Briggs 1986, Jackson 1991, Sebens 1994, Gray 1997, Reaka-Kudla 1997, Roberts et al. 2002, Rohwer et al. 2001, 2002). However, studying this diversity is often hampered by the logistics involved in conducting research in tropical areas and the difficulties of extracting small organisms from the reef itself. For several years, we have conducted a survey of marine invertebrates in the eastern Caribbean, on and around the coral reefs of Guana Island, British Virgin Islands. The survey has yielded numerous new genera and species of marine invertebrates (e.g., Martin 2002, Haney and Martin 2004, Fitzhugh, in press a, b, Felder and Martin 2003) as well as material for molecular phylogenetic studies (e.g., Wetzer et al. 2003). Although several collecting methods were employed during the course of the survey (hand collecting while snorkeling or SCUBA diving, light traps, yabby pumps, baited traps, etc.), some of the most productive sampling (both in terms of the number of specimens and the number of new species recovered) resulted from the use of what we have termed "artificial reef matrix structures" (ARMS). In this paper, we discuss the materials used to build ARMS, their construction, deployment, and harvesting, and some of the preliminary results obtained from our survey.

MATERIALS AND METHODS

Construction

ARMS consist of a 2-part structure (Figure 1). The top section is intended to mimic a coral head and is composed of a stack of 4 concrete plates and 2 types of algae-mimicking material. The bottom section consists of a "rubble basket" made of one-half inch plastic mesh lined with finer-mesh nylon or fiberglass window screen, suspended from a frame of 2.5 cm (1") dia PVC pipe.

For the top section, the 3 top-most plates were made by pouring a sand-patch concrete mix into cardboard molds. Plastic trash bags were used to line the inner surface of the cardboard molds so that the plates could be removed easily from the forms after drying. For the molds we used cardboard forms (from boxes used to hold twelve 750-ml bottles). This mold produces a plate about 36 x 27 x 6 cm. Minimal water was used in making the concrete mix, which allowed the mix to be sufficiently viscous to mold tunnels of various diameters using different sizes of PVC pipe. Tunnels are semi-circular impressions extending about 21 cm across the bottom surface of the slab, with alternating openings on either side of the long axis (Figures 1, 2A). Into the top-most plate were molded 6 tunnels using sections of 1.2 cm (0.5") dia PVC, which were pressed into the wet concrete and then removed. Four tunnels were molded into the second plate using 2.5 mm (1") dia PVC, and 2 tunnels were molded into the third plate using 5 cm dia PVC. The bottom-most plate was slightly wider, longer, and thinner (about 42 x 29 x 5 cm) than the other plates and was formed using the cardboard tray from a case of canned soda. No tunnels were formed in this plate. The dried plates were stacked and bound together with plastic cable ties (36 mm and 124 mm). Plates could be removed from the molds and deployed less than 24 h after the concrete was mixed. A piece of latex-coated coconut husk fiber pad (Frost King ™ washable furnace filter), cut to fit the dimensions of the top plate, was tied to the top plate, and 6 round, nylon pot scrubber pads (about 12 x 8 x 4 cm) were attached at various points on the stack (see Figures 1, 2A).
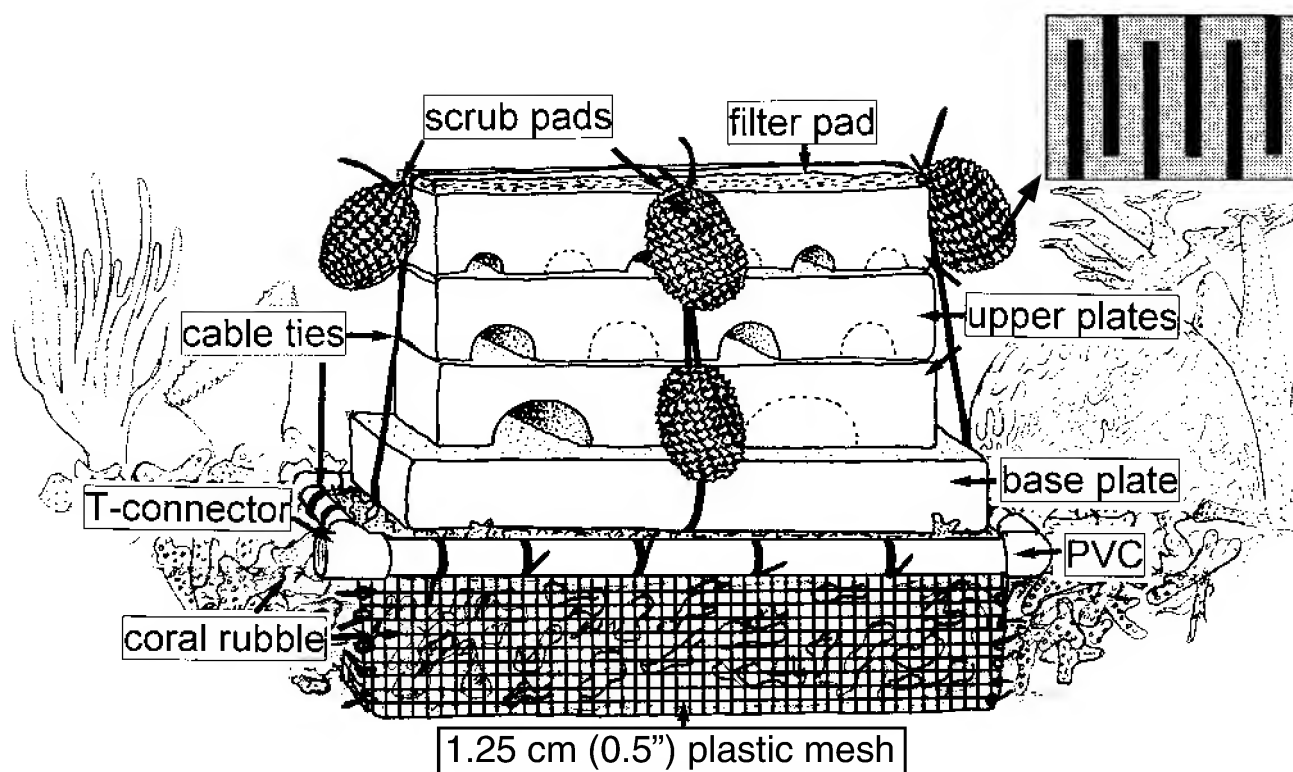
Figure 1. Diagram of a completed ARMS in place, cutaway view showing rubble basket beneath plates. Inset at upper right is a schematic view of the underside of the top plate, showing alternating tunnel orientation. Dashed lines on concrete plates indicate approximate location of tunnels having openings on the opposite side (not visible in this view).

The rubble basket beneath the concrete plates consisted of a square frame (0.5 m x 0.5 m) of 2.5 cm dia PVC pipe joined with two 90° elbows and two "T" connectors. The "T" connectors provided openings in the PVC frame at opposite corners of the frame. These openings allowed invertebrates to enter the pipe and, by allowing water in, facilitated the submergence of the frame. A 10-cm deep basket was made from sheets of 1.2-cm mesh extruded black plastic, joined at the corners by plastic cable ties of various sizes. An inner liner of plastic/fiberglass window screening with finer mesh size (about 2 mm) was placed into the basket. The basket was attached to the frame using plastic cable ties.

Total cost of materials for a single ARMS (concrete, PVC pipe, trash bags, furnace filter, scrub pads, cable ties, plastic 0.5" mesh, window screening) was less than US$20. The PVC, cardboard molds (boxes), and cement mix were purchased in the BVI; other materials were packed and shipped as luggage.

Deployment and retrieval

Deployment and retrieval of the ARMS was carried out by a team of 2 to 4 SCUBA divers operating from a small boat. The upper (concrete) section of the ARMS, which weighed about 29.55 kg (65 lbs), was lowered to the

sea floor using a rope; it was then carried by a diver to the desired location. Once an ARMS was in the desired place, the divers dug a depression in the sand and coral rubble, and the rubble basket was placed into this depression so that the PVC frame was more or less flush with the bottom. The basket was then filled with rubble. The concrete plates of the upper section were then placed atop the basket, and the entire assembled ARMS was left in place for about one year.

To retrieve the ARMS, each scrub pad, and the top filter pad, was carefully removed in situ by divers and sealed in a labeled plastic bag. The bound concrete plates were then placed into a large nylon duffel bag, bound with nylon webbing, and sent to the surface with an airlift bag guided by a diver. The rubble basket was then placed into a second duffel bag, bound with nylon webbing, and sent to the surface in the same manner. Each duffel bag was placed into a large plastic wash tub and transported quickly to shore. On shore, the concrete plates were separated and photographed, individual specimens were collected by hand, and the surfaces of the plates were scraped to obtain as many of the attached invertebrates as possible. The rubble from the basket was sorted by hand and then subjected to a dilute seawater-formalin bath to extract any additional animals.
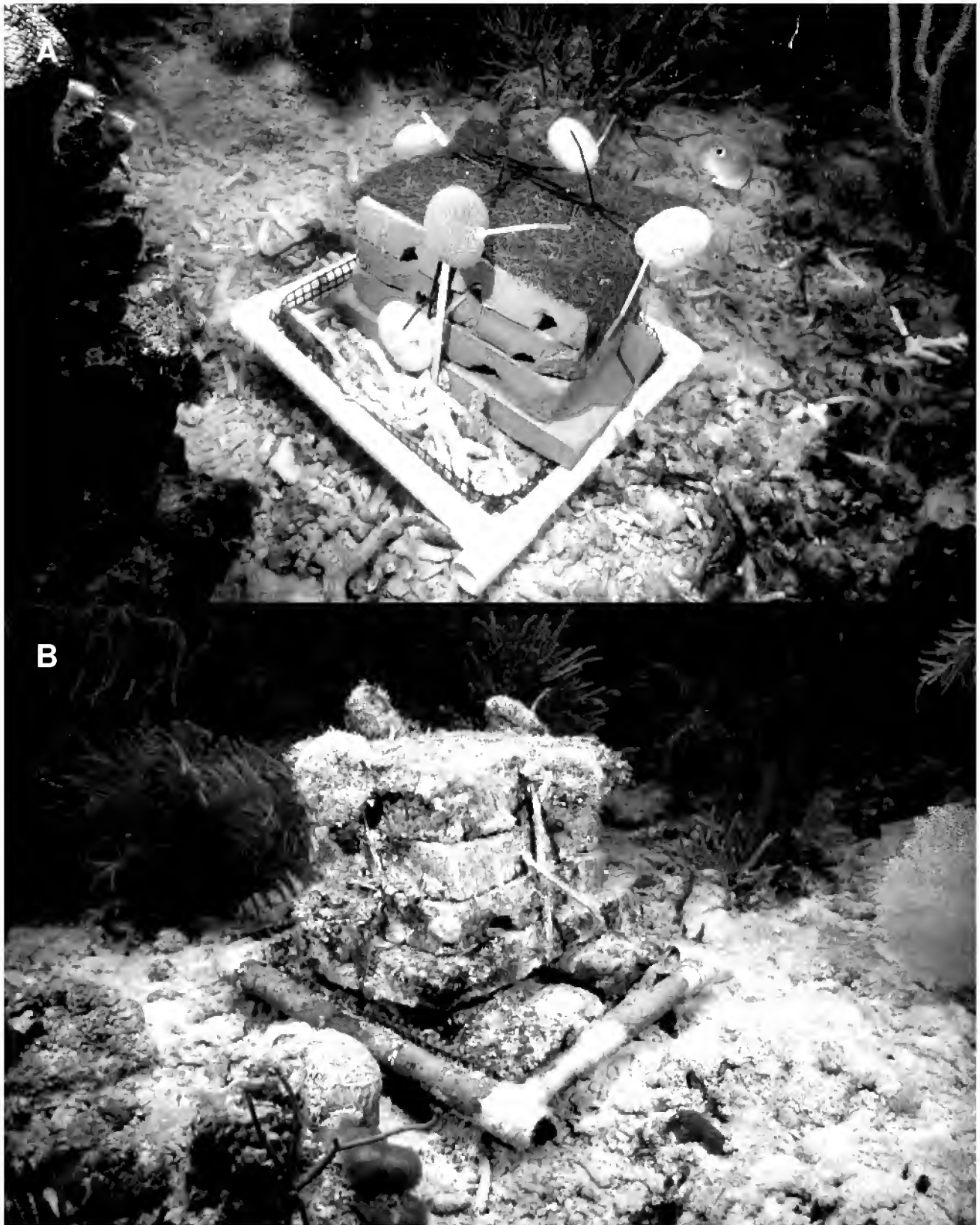
Figure 2. Photographs of two of our ARMS in the field. A) recently deployed ARMS in place at Long Point, Guana Island. B) the ARMS at Bigelow Beach (Guana Island) after about 1 yr in the field.

TABLE 1

Number of specimens of selected taxa found within one pot scrubber pad removed from the ARMS collecting device at Pelican Ghut (Atlantic side, BVI 2000, 96A3) and from 2 pads removed from the ARMS at North Beach (BVI 2000, 97A3 and 97A1). *Numbers for tanaids and isopods at North Beach 97A1 ARMS pot scrubber pad are possibly slightly off, as many of the specimens originally determined to be isopods were later determined to belong to the Tanaidacea. However, the total number, 631 for isopods and tanaids combined, is accurate.

	Pelican Ghut	**North Beach 97A3**	**North Beach 97A1**
Annelida			
Polychaeta	177	333	656
Crustacea			
Isopoda	67	6	401*
Ostracoda	5	23	228
Amphipoda	4	17	59
Caprellidea	0	0	1
Cumacea	0	5	0
Tanaidacea	16	13	230*
Copepoda	10	69	84
Leptostraca	0	0	42
Mollusca			
Bivalvia	6	12	43
Gastropoda	19	62	213
Polyplacophora	1	0	12
Nemertea	3	0	0
Nematoda	0	0	3
Echinodermata	1	11	32
Platyhelminthes	0	0	2
Cnidaria	0	0	2
Insects (chironomids)	0	0	44
Other insects	0	0	1
Sipunculida	0	0	8
Pycnogonida	0	0	7
Porifera	sponge fragments	sponge fragments	sponge fragments

RESULTS

Within days of being deployed, fish and shrimps were observed inhabiting the tunnels in the concrete plates. At the end of one year (when the ARMS were retrieved), the structures were covered with fouling organisms (Figure 2B). The pot scrubber pads, top filter pad, and rubble basket yielded the greatest number of individuals. The tunnels in the plates contained mainly fishes and encrusting organisms (polychaetes, molluscs, tunicates, and sponges), with occasionally larger, non-sessile invertebrates (ophiuroids, polychaetes, etc.). Stomatopods and large alpheid shrimps were commonly found inhabiting the PVC frame of the basket. Photographs of many of the species collected to date can be viewed on our preliminary project web site (see URL at Zimmerman and Martin, 2000–2003).

Pot scrubber pads are a commonly used device for quantitatively sampling small invertebrates after a colonization period (e.g., see Schoener 1982, Gee and Warwick 1996). In our study on Guana Island, the relatively fine mesh of the pads yielded high numbers of small worms and peracarid crustaceans. Preservation of the organisms was superb, providing us with specimens with delicate appendages still attached. Table 1 is an example of the quantity of specimens collected from these small pads.

Compared to the costs of constructing, deploying, and retrieving the ARMS, the cost of sorting and identifying the collected organisms is by far the greatest expense incurred. For 2 people working about full time (8 h/d), the time needed to sort specimens from the pad, and from the sediment trapped within the pad in some cases, and to identify them to phylum or to lower taxon as well as separate them and count individual specimens, was between 8

and 9 d (8.5 d for Pelican Ghut, 9 d for North Beach 97A3, and 9 d for North Beach 97A1).

The more open structure of the furnace filter pads was colonized by both small and slightly larger invertebrates (worms, molluscs, small decapods, etc.).

DISCUSSION

Although there is a vast amount of published literature on the use of artificial reefs, most of the interest has focused on large-scale reefs created and studied for fisheries purposes (e.g., see papers presented at the Florida Artificial Reef Summit 2001, on the web at: http://www.broward.org/bri01908.pdf; supplement 59 to ICES [International Council for the Exploration of the Sea] *Journal of Marine Science*, October, 2002; and *Bulletin of Marine Science*, vol. 55, numbers 2–3). Use of artificial reefs or other artificial substrates as a collecting source for reef-associated invertebrates also has a fairly long history (e.g., Schoener, 1974, 1982, Virnstein and Curran 1986, Edgar 1991). What is unusual, and to our knowledge novel, about the ARMS is the combination of substrates (concrete, furnace pads, scrub pads, PVC pipe, and coral rubble) to mimic a reef area in microcosm.

A single ARMS provided a much greater abundance and diversity of organisms (especially delicate and/or highly motile decapod crustaceans) than the same team of divers could collect by hand, as compared to results from our previous collecting efforts. In addition to providing us with undescribed species (e.g., *Microprosthema jareckii* Martin 2002), in many cases (e.g., stomatopods) a single ARMS provided more individuals of a given species than were collected by divers in the entire previous field season. Thus, ARMS are an effective way of collecting large numbers of marine invertebrates with relatively little effort, cost, or disturbance to the reef.

The rubble baskets placed beneath the ARMS served a three-fold purpose. First and foremost, these baskets collected additional invertebrates that were either attracted to or were already resident in the coral rubble in each basket. Second, these baskets created a secondary "catch" zone for invertebrates that might immediately flee the ARMS when it was retrieved. Such escapes often occur when a shrimp or stomatopod quickly exits the ARMS and immediately burrows, and by placing a basket beneath each ARMS we hoped to circumvent this type of loss. Third, the baskets allowed us to place each ARMS on a uniform substrate that was flush with the surrounding seafloor.

The use of ARMS as described herein does not guarantee a representative sample of marine invertebrates living on or in a reef ecosystem. Organisms having an asso-

ciation/dependence with live algae or live coral, as well as boring animals (e.g., some polychaetes, sipunculans, burrowing barnacles), may be under represented. ARMS appear to mimic the physical attributes and habitats of reefs. In this sense, the ARMS are obviously very selective devices, as is true of all artificial reefs.

ACKNOWLEDGMENTS

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Gulf and Caribbean Research

Northern Range Extensions for *Caprella scaura* Templeton, 1836 (Crustacea: Amphipoda: Caprellidae) on the Florida Gulf Coast and in South Carolina

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NORTHERN RANGE EXTENSIONS FOR *CAPRELLA SCAURA* TEMPLETON, 1836 (CRUSTACEA: AMPHIPODA: CAPRELLIDAE) ON THE FLORIDA GULF COAST AND IN SOUTH CAROLINA

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ABSTRACT Previous northwestern Atlantic records for the caprellid amphipod *Caprella scaura* Templeton, 1836 were confined to St. Croix (US Virgin Islands), St. Barthélemy, and Puerto Rico, islands bordering the northern Caribbean Sea. Based on recent collections, *C. scaura* is now reported from the Gulf of Mexico (St. Andrew Bay, Florida) and the US east coast (Charleston Harbor, South Carolina). These constitute the first records for this apparently non-indigenous species in waters of the continental eastern United States, establishing considerable northern range extensions for *C. scaura* in the northwest Atlantic.

INTRODUCTION

During the past 2 years we collected specimens of *Caprella scaura* Templeton, 1836 from the Gulf of Mexico (GOM) and east coast of North America, which represent the first Atlantic records for this caprellid amphipod in the continental United States. The purpose of this report is to document these new records.

Caprella scaura was originally described from Mauritius in the Indian Ocean (Templeton, 1836). Unfortunately, the authors have not been able to determine if the type material is extant. McCain (1968) lists numerous records for this widely distributed species, giving locations from the mid-latitudes to the tropics, in both northern and southern hemispheres, in all oceans except the Arctic, and reports its habitat as red and brown algae, seagrass, bryozoans, and on a sea urchin. There have been no published records for this large caprellid amphipod from the coastal waters of the eastern United States. In the northwestern Atlantic, the only records for *C. scaura* are from the tropical waters of St. Croix (US Virgin Islands), St. Barthélemy, and Puerto Rico, all islands bordering the Caribbean Sea (McCain 1968).

Representative specimens of *C. scaura* collected during this study have been deposited in the Gulf Coast Research Laboratory Museum (GCRL), Ocean Springs, Mississippi, and in the reference collection of the Southeastern Regional Taxonomic Center (SERTC), South Carolina Department of Natural Resources (SCDNR), Charleston, South Carolina.

MATERIAL EXAMINED

West Florida, Panama City Beach. 12♂♂, 19 subadult ♂♂, 19♀♀ (4 ovig.), 10 subadult ♀♀, 7 juveniles, GCRL 2054, West Pass jetties, 30°08.60'N 85°42.20'W, wash of submerged rocks, 23 June 1998, coll. J. Foster; 8 subadult ♂♂, 4 ovig. ♀♀, 8 subadult ♀♀, 1 juvenile, GCRL 2053, West Pass jetties, St. Andrew State Park, among algae on submerged rocks, 20 February 1999, coll. J. Foster; 2♂♂, 1 subadult ♂, 1♀, 1 ovig. ♀, GCRL 2051, West Pass, scrape of channel marker R16, 9 July 1999, coll. J. Foster; 11♂♂, 11 subadult ♂♂, 2♀♀, 10 ovig. ♀♀, 12 subadult ♀♀, 1 juvenile, GCRL 2052, St. Andrew Bay, Florida, on submerged rocks adjacent to seawall, Panama City Marina, 30°09.84'N 85°39.77'W, 28 December 2002, coll. J. Foster.

South Carolina, Charleston Harbor at Ft. Johnson, in scrapings from floating dock, SCDNR boat slip, 32°45.15'N 79° 53.94'W, 30♂♂, 15♀♀ (5 ovig.), 8 intermediate juveniles (SERTC Catalogue Number S-87), 4♂♂, 4♀♀ (GCRL 2063), 28 February 2002, coll. D. Knott and R. Heard; 3♂♂, 4♀♀ (SERTC Catalogue Number S-88), 12 July 2002, coll. D. Knott; 21♂♂, 5♀♀ (4 ovig.), GCRL 2062, 21 February 2003, coll. R. Heard, B. Thoma, and J. Thoma.

OBSERVATIONS

Florida Gulf Coast (St. Andrew Bay)

On 23 June 1998, during routine examination of rock washings from West Pass jetties, St. Andrew Bay, Florida, a previously unobserved species of amphipod, *Caprella scaura*, was identified. Specimens were collected at a depth of 1–2 m, where they were associated with algae and hydroids on the jetties, along with another large caprellid
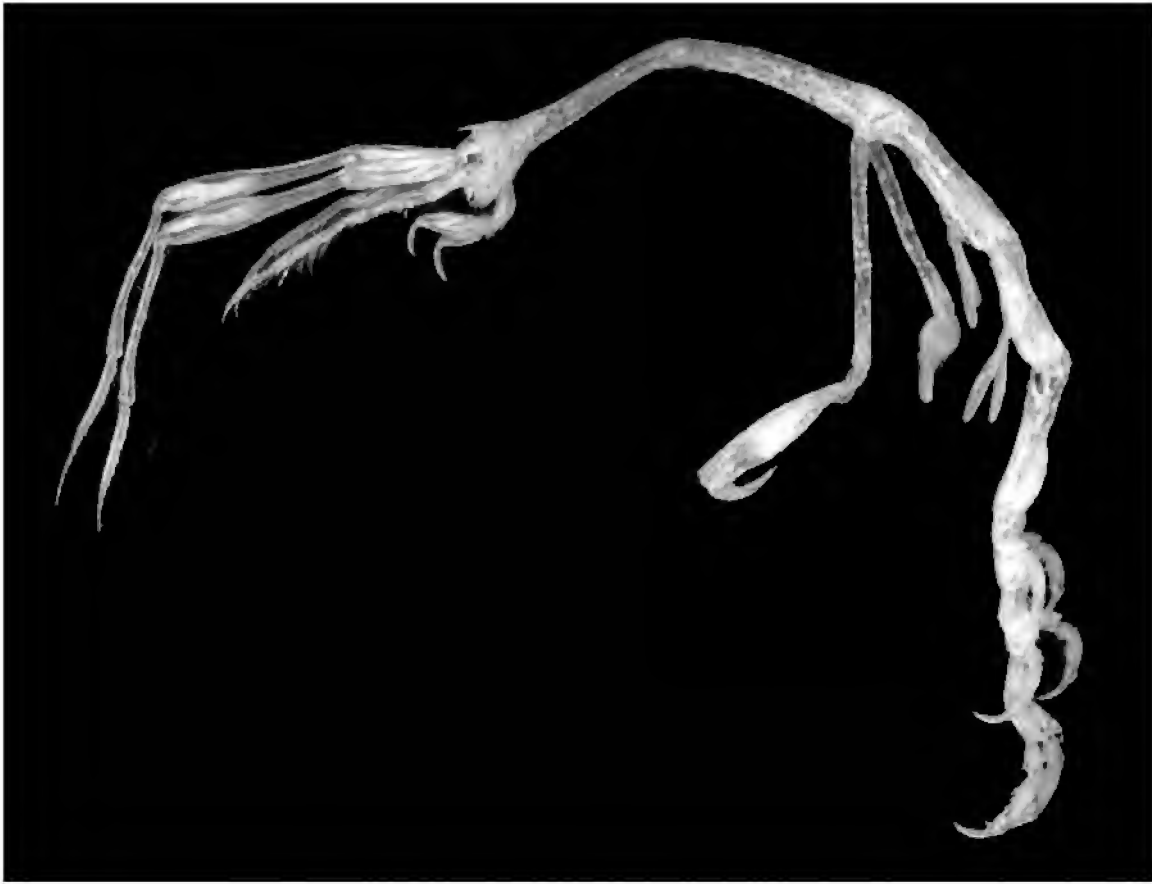
Figure 1. *Caprella scaura.* **Adult male (10 mm) from rock jetties at entrance of St. Andrew Bay, Florida, 23 June 1998. Scanned image, lateral view.**

species, *Caprella equilibra* Say, 1818. *Caprella scaura* was collected subsequently on 20 February 1999, 9 July 1999, and 28 December 2002 from another site on the West Pass jetties, and from channel markers in association with the barnacle *Megabalanus antillensis* (Pilsbry, 1916) and other fouling organisms, e.g., the amphipods *Laticorophium* cf. *baconi* (Shoemaker, 1934), *Podocerus brasiliensis* (Dana, 1853), *Stenothoe* spp., *Erichthonius brasiliensis* (Dana, 1853), *Cymadusa compta* (Smith, 1873), *Ampithoe valida* Smith, 1873, and the tanaidacean *Leptochelia dubia* Krøyer, 1842.

US east coast (Charleston Harbor, South Carolina)

As part of a survey of peracarid crustaceans in Charleston Harbor and surrounding waters, numerous individuals of *Caprella scaura* (including mature males, females, and juveniles) were recovered from scrapings off a floating dock in the boat slip of the South Carolina Department of Natural Resources, Ft. Johnson (28 February 2002, 12 July 2002, and 21 February 2003). Other epibenthic invertebrates found associated with *C. scaura* included: the amphipods *Caprella equilibra* Say,

1818, *Paracaprella tenuis* Mayer, 1903, *Jassa* cf. *marmorata* Holmes, 1903, *Gammarus mucronatus* Say, 1818, *Gammarus palustris* Bousfield, 1969, *Elasmopus levis* Smith, 1873, *Stenothoe* sp., *Laticorophium* cf. *baconi* (Shoemaker, 1934), and *Monocorophium acherusicum* (Costa, 1857); the decapod crustaceans *Palaemonetes vulgaris* (Say, 1818), *Petrolisthes armatus* (Gibbes, 1850), *Dyspanopeus sayi* (Smith, 1869), *Eurypanopeus depressus* (Smith, 1869), and *Zaops ostreum* (Say, 1817); the isopod *Paradella dianae* (Menzies, 1962); and the polychaetes *Nereis succinea* (Frey and Leukart, 1847), *Nereiphylla fragilis* (Webster, 1879), *Sabellaria vulgaris* (Verrill, 1873), and an undetermined syllid. These motile species inhabited a thick growth of solitary ascidians [*Molgula manhattensis* (DeKay, 1849), Styela plicata (Lesueur, 1823)], hydroids [*Obelia* sp.], bryozoans [*Bugula neritina* (Linnaeus, 1758), *Amathia* spp.], sponges [*Hymeniacidon heliophila* (Parker, 1910)], and bivalve mollusks [*Brachidontes exustus* (Linnaeus, 1758), *Crassostrea virginica* (Gmelin, 1792)].

Figure 2. *Caprella scaura*. **Adult male (18 mm) and ovigerous female (8 mm) from floating dock near entrance of Charleston Harbor, South Carolina, February 2002. Digital photograph, lateral views.**

REMARKS

Records established in this study extend the range of *Caprella scaura* northward to the northeastern GOM (St. Andrew Bay) and the coast of South Carolina (Charleston Harbor). This represents an extension of greater than 2500 km.

Caprella scaura is remarkable because of its size. McCain (1968) reported males and females as long as 21 mm and 12 mm, respectively; however, the adult males we collected during the summer from rock jetties at the entrance to St. Andrew Bay had lengths (anterior end of cephalon, excluding antennae, to posterior end of abdomen) of 10 mm (Figure 1), and adult females were distinctly smaller, with maximum lengths of 6–8 mm. The largest male and female specimens from Charleston Harbor were collected during the winter (lengths of 18 mm and 8 mm, respectively) (Figure 2), while the corresponding sizes of those collected there during the summer were 10 and 5 mm. These size differences may be due to seasonal effects, as one of us (R. Heard, pers. comm.) noted for *Caprella equilibra*. For example, individuals, especially males, in winter populations reach much larger sizes than those observed during the summer months in Georgia coastal waters. These apparent ecophenotypic differences in size may be related to a decrease in predation during the colder months, in conjunction with the dampening effects

of low temperature on reproductive activity. *Caprella equilibra* collected in Georgia during the winter appeared to attain a much larger size prior to the onset of reproduction in spring; whereas, specimens collected during summer were sexually mature at a much smaller size (R. Heard, per. observations). Notwithstanding, examinations of additional winter and summer collections from St. Andrew Bay and Charleston Harbor, respectively, are needed to determine if these seasonal size differences consistently occur in *C. scaura*.

The acute anteriorly directed cephalic spine on *Caprella scaura* clearly distinguishes this species from the sea turtle associate *C. andreae* Mayer, 1890, and the common near shore GOM species, *Caprella penantis* (Leach, 1814), both of which possess a triangular cephalic process. Another distinguishing character for males of *C. scaura* is the equivalence in the length of the basis of gnathopod 2 and the length of pereonite 2. The only western Atlantic species that approximates this ratio is *C. linearis* (Linnaeus, 1767), but in this species, the head bears no process. Additional distinguishing characters include the fused articles of the flagellum of antenna 1 in males and the raised dorsomedial processes located on the abdomen of both sexes.

Caprella scaura was not listed in previously published studies of the caprellid fauna inhabiting all or part of the northwestern Atlantic (Steinberg and Dougherty 1957,

McCain 1968). It is also absent from records of more extensive surveys of the South Atlantic Bight invertebrate fauna (Pearse and Williams 1951, Dörjes 1972, 1977, Frankenberg and Leiper 1977, Zingmark 1978, Wenner et al. 1983, 1984, Fox and Ruppert 1985, Wendt et al. 1985, Prezant et al. 2002) and from unreviewed faunal checklists and reports (Heard and Heard 1971, Calder et al. 1976, Kirby-Smith and Gray 1977, Vittor and Associates 2000).

Caprella scaura is also missing from previous studies that deal with caprellids from the GOM, particularly those of Steinberg and Dougherty (1957) and Caine (1974). Camp et al. (1998), in an extensive checklist of malacostracans from the GOM, did not list *C. scaura*. The species was not listed in a faunal study of St. George Island, Florida, by Menzel (1956), an inventory of Texas jetty communities (Whitten et al. 1950), or from reports on the near shore coastal habitats of Perdido Key, Florida (Rakocinski et al. 1993, 1996). *Caprella scaura* is absent from several unpublished reports dealing with the fauna of St. Andrew Bay, Choctawhatchee Bay, and Perdido Key, Florida (Saloman, 1976, Saloman et al. 1982, Livingston 1986, Foster 2000). Future investigations of the amphipod fauna of the northern GOM and the eastern US coast should include efforts to recover more specimens and to observe the seasonality, breeding behavior, and the northward encroachment and establishment of this apparently introduced and widely distributed species. One explanation for recent occurrence of *C. scaura* in both St. Andrew Bay and Charleston Harbor may be passive transport of individuals in ship-fouling communities or in ballast water. Both Charleston and Panama City (at St. Andrew Bay) are active ports for international maritime transport and commerce.

The first published report of *C. scaura* from the coasts of North America was made by Marelli (1981), who documented the occurrence of this species in Humboldt Bay, San Francisco Bay, California, and in Elkhorn Slough, a small estuary associated with Monterey Bay, California. Marelli (1981) also reported *Caprella mutica* Schurin, 1935, a species described from the Sea of Japan, from the same region. Subsequent reports of *Caprella mutica* from Massachusetts (Pederson 2002) and Maine (S. LeCroy, pers. comm., GCRL, Ocean Springs, MS) added to the understanding of the distribution of non-indigenous members of the family Caprellidae in North America.

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First Record of Bonefish, *Albula vulpes*, from Mississippi Coastal Waters

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SHORT COMMUNICATION

FIRST RECORD OF BONEFISH, *ALBULA VULPES*, FROM MISSISSIPPI COASTAL WATERS

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INTRODUCTION

Bonefish (*Albula* spp.), Family Albulidae, occur worldwide in coastal waters of tropical and warm temperate seas (Crabtree et al. 1997), and 2 species, *A. vulpes* and *A. nemoptera*, are recognized from the western Atlantic Ocean (Rivas and Warlen 1967). The normal range of *A. vulpes* in the western Atlantic extends from Bermuda to Brazil, including the Bahamas, Cuba, Mexico, Central America and the Antilles (Hildebrand 1963), but in US waters, *A. vulpes* typically occurs off south Florida (Crabtree et al. 1997). In contrast, *A. nemoptera* has been reported from Panama, Colombia, Venezuela, Jamaica and Hispaniola (Uyeno et al. 1983).

Published accounts of *A. vulpes* from the northcentral Gulf of Mexico (hereafter GOM) are rare. Ogren and Brusher (1977) collected a single specimen of *A. vulpes* from St. Andrew Bay, Florida but did not report its size. Thompson and Deegan (1982) reported the collection of 3 *A. vulpes* leptocephali (range: 34.8–53.5 mm standard length (SL)) from Louisiana coastal waters, and Boschung (1992) reported a single *A. vulpes* juvenile (37 mm SL) collected from Grand Bay, Alabama. We report the first record of *A. vulpes* from Mississippi.

MATERIALS AND METHODS

On 4 November 1999, a single specimen of *A. vulpes* was caught off the eastern tip of Petit Bois Island (30°12'N, 88°25'W) in Mississippi Sound by an angler using hook-and-line. The specimen was caught during day time from shallow water (0.5 m) over a sandy bottom.

Species identification followed Hildebrand (1963), and SL and total length (TL) were measured to the nearest millimeter (mm). Wet weight was recorded to the nearest 1.0 g. The gonads were removed, preserved in 10% buffered formalin and processed for histological assessment following standard procedures. The stomach contents were also examined. The specimen resides in the Mississippi Department of Marine Resources fish collection.

RESULTS AND DISCUSSION

The specimen (Figure 1) measured 200 mm SL (241 mm TL), weighed 112 g, had an empty stomach, and histological analysis indicated it was an immature female. Age-length data from south Florida (Crabtree et al. 1996) suggest the specimen was < 1 year old.
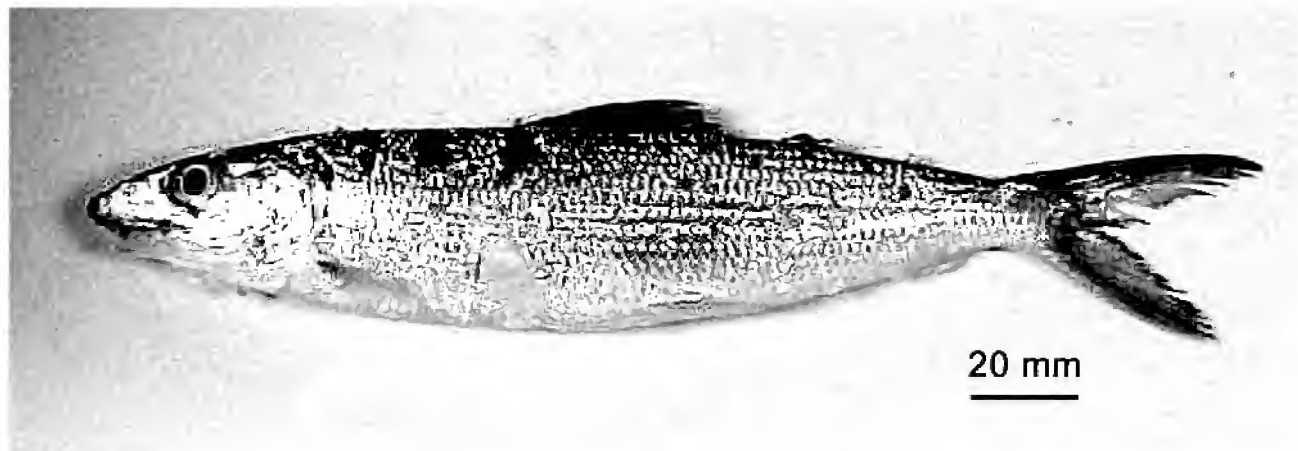

Figure 1. Photograph of a 200 mm SL *Albula vulpes* collected from Mississippi coastal waters.

The fact that a juvenile *A. vulpes* was caught from Mississippi waters, far from its normal range, warrants special interest. Historically, *A. vulpes* has not been encountered during routine fisheries independent monitoring and assessment activities conducted in Mississippi coastal waters from 1967 to 2003 (IJFMAP-M, Gulf Coast Research Laboratory), nor has the species been reported from Mississippi's marine recreational fishery from 1979 to 2003 (MRFSS, http://www.noaa.gov/ess.fish-habit.html). The specimen reported here represents the first record of *A. vulpes* from Mississippi and the second record of a juvenile from the northcentral GOM.

Oceanic circulation processes such as Loop Current intrusion into the northern GOM may transport and disperse GOM and Caribbean fauna into the northern GOM (Schroeder 1992, Perry et al. 1998, Johnson and Perry 1999, Johnson et. al. 2001). Thompson and Deegan (1982) suggested a Loop Current spin-off eddy to explain the presence of *A. vulpes* leptocephali off Louisiana. Furthermore, larval transport on ocean surface currents was considered the likely mechanism responsible for the unprecedented occurrence of bonefish leptocephali in Long Island Sound, New York (Alperin and Schaefer 1964).

Bonefish have a prolonged November–June spawning season off south Florida (Crabtree et al. 1997) and most likely in the northwestern Caribbean Sea as well. During Spring 1999, satellite imagery (NOAA-AVHRR) of sea surface temperature (SST) revealed the Loop Current as a strong intrusion of warm Caribbean water onto the northern GOM shelf (D. Johnson, pers. comm., GCRL, Ocean Springs, MS), suggesting a possible mechanism for the transport of the specimen, as a leptochephalus larva, into the northern GOM. Furthermore, hydrologic conditions in the southernmost region of eastern Mississippi Sound during spring–fall of 1999 (17.0–30.5 °C, 24.0–34.0 psu) were likely conducive to survival and growth, based on known temperature (Alperin and Schaefer 1964) and salinity (Pfeiler 1981) requirements for young bonefish.

ACKNOWLEDGMENTS

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Notes on Aquarium Brood Release and Feeding of the Opossum Pipefish, *Microphis brachyurus lineatus*

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SHORT COMMUNICATION

NOTES ON AQUARIUM BROOD RELEASE AND FEEDING OF THE OPOSSUM PIPEFISH, *MICROPHIS BRACHYURUS LINEATUS*

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INTRODUCTION

The opossum pipefish, *Microphis brachyurus lineatus*, is a migratory syngnathid with a salmon-like life history (Frias-Torres 2002). Adults breed in freshwater and oligohaline habitats associated with emergent vegetation, mostly *Panicum* sp. and *Polygonum* sp.; breeding occurs during the wet season (May to November) (Gilmore and Hastings 1983). In southern Mexico, opossum pipefish associate with *Ruppia maritima*, and reproduction is year-round (Miranda-Marure et al. 2004). Pelagic juveniles are found in the Atlantic Ocean and are associated with *Sargassum* sp. (Böhlke and Chaplin 1968). Juveniles eventually recruit into oligohaline habitats. The species range is from Sao Paulo, Brazil, to New Jersey, USA, although the northernmost limit of permanent breeding populations occurs in the freshwater tributaries to the Indian River Lagoon in east central Florida (Gilmore and Gilbert 1992). The opossum pipefish is one of 25 species of diadromous fish at risk of extinction in North America (Musick et al. 2000) and is a candidate species to the US Threatened and Endangered Species List (Federal Register 1999).

The opossum pipefish diet was unknown until Teixeira and Perrone (1998) analyzed the gut contents of 109 opossum pipefish from the southeastern Brazil population. They found that the most abundant prey were insect larvae, followed by juvenile fish (Gerreidae) and small crustaceans. However, the diet necessary to maintain aquarium-kept opossum pipefish had not been determined prior to the present paper.

Male Syngnathidae (seahorses and pipefishes) carry a brood of fertilized eggs in a partially or completely closed pouch, depending on the species. Hatching occurs inside the pouch, followed by release of the young syngnathids.

Brood release has been documented for common pipefish and seahorse species that have been succesfully kept in aquaria (Garrick-Maidment 1997). Gilmore (1977) reported opossum pipefish brood release in a freshwater aquarium, but the actual event of brood release was not observed. Long-term aquarium keeping of opossum pipefish has not been attempted before, and many fundamental questions of the biology of the species remain unresolved.

In 350 BC, Aristotle was the first scientist to describe the process of brood release in Syngnathidae, probably *Syngnathus acus*, a common pipefish with a pouch covered by a fleshy membrane found in inshore coastal areas of the Mediterranean Sea:

"When the time of parturition arrives, [the pipefish] bursts in two, and the eggs escape out (...) the fish has a diaphysis or cloven growth under the belly and abdomen, and after it has spawned by the splitting of this diaphysis, the sides of the split grow together again. (...) The young fish cluster round the parent (...) for the fish spawns onto herself; and if any one touch the young, they swim away."

The goal of the present study was to gain insight into adult feeding and brood release of opossum pipefish in captivity as a step towards a better understanding of the biology of the species. Two primary objectives were: 1) to apply Teixeira and Perrone's field observations to the diet supplied to captive opossum pipefish and 2) to video record an opossum pipefish brood release event.

METHODS

Male-female pairs of opossum pipefish were collected at the Fellsmere Canal, Sebastian River, east central Florida, during the wet season (May to November) of 2000. Collections were targeted to areas with underwater bank vegetation using a 30 x 40 cm square dipnet with an outer net of 4 mm and an inner net of 0.5 mm mesh size. Fish were transferred into 25 L coolers equipped with air-stones and filled with water and vegetation from the capture site. Additional *Panicum* and water were collected to establish aquaria in the laboratory. Adult male-female pairs and brooding males were transferred to freshwater 50 L glass aquaria fitted with standard undergravel filters and air stones. Several stems of *Panicum* were kept at the surface and half submerged. Illumination was set on a 13:11 light:dark cycle. Water and air temperature was kept at 25 °C.

Captive opossum pipefish were presented with a variety of dried and live food types (brine shrimp, amphipods,

freshwater shrimp and guppies) one at a time, and their reaction (consumption or rejection) over a 15 min observation period was recorded. Insect larvae were not tested as potential diet for captive opossum pipefish. Daily observation of embryo development determined when brood release was imminent. At that point, a 24 h watch was kept to allow for video recording of a brood release event.

RESULTS AND DISCUSSION

Opossum pipefish rejected brine shrimp (*Artemia salina*) and amphipods, the 2 most common types of dried and frozen foods usually sold in pet stores as ideal feeding for Syngnathidae. Opossum pipefish also rejected live amphipods but consumed all other types of live food offered: *A. salina* adults (which survive a few minutes in freshwater); juvenile freshwater glass shrimp (*Palaemonetes kadiakensis* Rathbun); fry, juveniles, and small adults of guppies (*Poecilia* sp.); and mosquitofish (*Gambusia* sp.). To ensure a constant suppy of food, wild and commercially available freshwater shrimp, guppies and mosquitofish were fed to the opossum pipefish.

Brood release occurred several times in aquaria. The actual event of larval release was first observed from a 132 mm SL brooding male, 9 d after capture. Male opossum pipefish have an open brood pouch under the tail, where eggs are protected with bilateral pouch plates but are not covered by a pouch membrane (subfamily Doryrhamphinae). Therefore, direct observation of every stage of larval release was possible. On August 22, 2000 a power outage interrupted the automatic light cycle at 2:00 PM. At 3:00 PM the male started to release the brood. During brood release, the male remained close to the bottom, in a diagonal head-up orientation. The male vibrated for 2 sec from side to side, whereupon a string of 5 to 6 eggs detached from the pouch in a tail-to-head direction. Beginning with the most distal egg, the egg membrane ruptured, releasing a curled larva. Released larva then uncurled and with an undulating movement swam away from the male. In the frontal and medial sections of the pouch, direct hatching (without a preliminary release of a string of eggs) was observed (Figure 1). In this case, the larvae were violently ejected from the pouch. The observed brood release event lasted 35 min. In comparison, release of the seahorse brood (*Hippocampus* sp.) was preceded for up to 12 h of contractions, with the actual release taking just a few seconds (Garrick-Maidment, 1997).

Aquarium observations suggest that in the wild, opossum pipefish brood release occurs at dusk or at night. The power outage in the early afternoon, and the observed hatching that followed the dark period seems to confirm a

Figure 1. A 135 mm SL male opossum pipefish, *Microphis brachyurus lineatus*, releasing a 6 mm larvae. Sequence extracted from a 54 minute video recording.

dusk or nocturnal preference for larval release. Larval release was observed and video recorded for other brooding males during the wet season of 2000. All males followed a similar pattern of release at dusk, or soon after midnight, with vibrations preceding pouch release. In cases when the brood release was not observed, larvae were first seen swimming in the aquarium either late at night or just after sunrise.

Acknowledgments

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Introduction to Special Section on Research Activities at the Iztacala Campus of the Universidad Nacional Autónoma de México, México

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INTRODUCTION TO SPECIAL SECTION ON RESEARCH ACTIVITIES AT THE IZTACALA CAMPUS OF THE UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO, MÉXICO

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In October 2002, we had the opportunity to initiate a long-term collaboration with colleagues from the Iztacala campus of the Universidad Autónoma de México (UNAM), whose research interests focus on coastal and nearshore fishes and decapod crustaceans of Veracruz state, Mexico. This is an undergraduate campus with a strong Biology department whose faculty also maintain research programs despite limited sources of funding and a heavy teaching load. During the course of our initial visit, we realized that there is a wealth of unpublished undergraduate student research on understudied fish species.

In Mexico and many other Latin American countries, students must research, write and defend an undergraduate thesis to receive a bachelor's (Licencia) degree in the sciences. Many of these theses represent research on little-studied organisms or ecological aspects of the Gulf of Mexico or Caribbean Sea. Unfortunately, the great majority of these works are never published in any format, owing to factors such as the student graduating and leaving, heavy teaching load of the faculty advisor, lack of encouragement for student publications, and language barriers. For example, the Biology department of the Iztacala campus of UNAM has graduated 1,463 students with the Licencia degree from 1981–2001, representing 1,463 senior theses during a 20 year period. Of the biology theses, 47.5% represent research in environmental areas, whereas the remaining 52.5% concentrated on medically-related fields such as genetics, physiology, and molecular and cellular biology. The majority of the environmentally-oriented theses focused on ecology and natural resources (Figure 1). Students undertaking marine-related environmental research projects at Iztacala collect their data over the period of one year at coastal field sites 4–6 hrs from campus under the supervision of their thesis advisors. The thesis advisors typically pool funds from extramural sources, the university and personal monies to support travel, housing, meals and other expenses for the students and the materials needed to complete the research projects. Samples are transported back to the laboratory, where students process and analyze the data during their senior year. The final thesis defense is a formal affair, with a presentation of the results to an examining committee consisting of 3 of the 5 committee members. Unfortunately, publication of the thesis is not part of the process, resulting in a wealth of valuable information unavailable to the scientific community (Figure 1).

We developed a collaborative partnership in November 2002 between the faculty advisors from the Biology department at UNAM-Iztacala, the Department of Coastal Sciences, The University of Southern Mississippi and non-profit funding organizations interested in research in the Gulf of Mexico and Caribbean Sea whereby exceptional senior and Masters theses from the Biology department at UNAM-Iztacala were processed and submitted for peer-review in *Gulf and Caribbean Research*. Once each thesis was translated into English, bilingual scientific writers/editors worked in collabo-
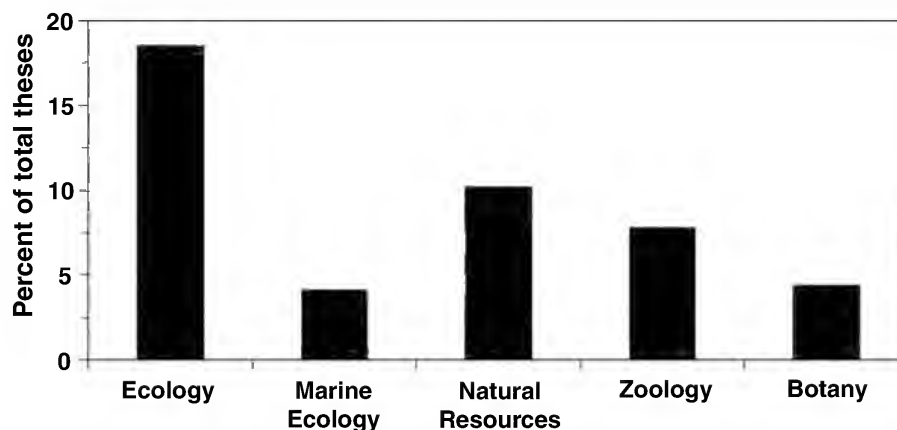
Figure 1. Plot of the percentage of environmentally-oriented undergraduate Licencia degrees by discipline from 1981–2001 from the Biology department at Universidad Nacional Autónoma de México-Iztacala. Total number of degrees granted during this period was 1,463.

ration with the faculty advisor to transform the manuscript from a thesis to a publishable article that was submitted for peer review. Publication of the first group of these theses follow in this issue of *Gulf and Caribbean Research*. The topics range from life history and reproduction, to trophic ecology, and parasites of understudied fishes from the southern Gulf of Mexico. As the process is completed, additional theses will appear in the next published volume of *Gulf and Caribbean Research*. The chosen theses represent a small percentage of the wealth of unpublished information from the Gulf and Caribbean region. Hopefully, this pilot program will inspire other institutions and funding agencies to initiate similar programs.

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Overview of Study Areas and UNAM-Iztacala Student Research

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OVERVIEW OF STUDY AREAS AND UNAM-IZTACALA STUDENT RESEARCH

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The State of Veracruz is located on the east coast of Mexico and consists of many shallow marine systems such as estuaries and coastal lagoons. These estuarine systems are ecological sites of great importance due to the interactions that occur between the intertidal zones and adjacent areas. This importance is reflected in the variety of natural components present in these sites as well as the large number of species that depend on this aquatic zone, such as birds, mammals, molluscs, crustaceans and fishes. Many of the crustaceans and fishes are consumed by the local inhabitants and distributed in commercial areas in Mexico City. It is estimated that Veracruz state is in fourth place in fisheries landings for the country, and contributes 10% of the total fisheries production.

Academic personnel from the laboratories of Ecology and Zoology in the Facultad de Estudios Superiores Iztacala, Tlalnapantla, Mexico have focussed their research efforts since 1988 on two of the systems in Veracruz state, the Tecolutla River and the lagoonal system of Alvarado (Figure 1). Research in both locations has resulted in a number of professional theses by undergraduate students in the Biology Department at UNAM-Iztacala.

Tecolutla River is a typical estuary located in the north region of the state, and is formed by the confluence of the Necaxa, Axacal, Cempoala and San Pedro Rivers. The headwaters of the river system begin in the Sierra Madre Oriental and run southeast to northeast for a total of 100 km. The predominant activity in the area is tourism.

In contrast, the Alvarado lagoonal system is located in the south-central portion of the state and is comprised of 3 lagoons, Alvarado Lagoon, Buen País Lagoon and Camaronera Lagoon, covering a total surface area of 12,000 hectares. This lagoonal system is associated with the Papaloapan River, whose watershed covers an area of about 39,189 km^2. The principal activity in the city of Alvarado is fishing, and the majority of the families in the city earn their living in this manner. The waters of the Alvarado Lagoon, the Papaloapan River and other minor rivers flowing into the Lagoon have a level of contamination of 40–60%, as a result of the diverse industries and population centers around the shores. As a consequence of this contamination, there has been a severe degradation in the ecological integrity of the lagoon, which has negatively impacted the fishing industry.
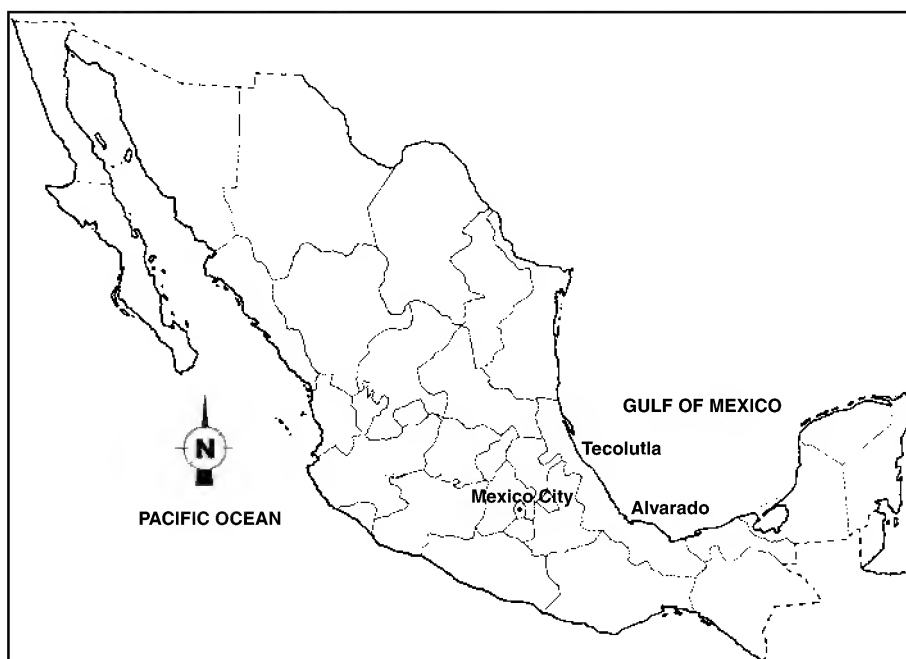
Figure 1. Map of Mexico showing areas of research in Tecolutla River and Alvarado Lagoon, and the physical relationship between sampling sites, and the location of the laboratory just north of Mexico City.

The majority of the research from Tecolutla River and the Alvarado lagoonal system has characterized the ichthyofauna of both systems based on the environmental changes of the hydrological characteristics. More than 80 species, representing 50 genera and 35 families of fishes have been recorded from these two systems. Much of the undergraduate work has focused on the biology of the most important families, including the Sciaenidae, Clupeidae, Cichlidae, Centropomidae, Gerreidae, Engraulidae, Syngnathidae, Belonidae, Batrachooididae, Gobiidae and Eleotridae. Research topics include information on the areas and times of reproduction, age and growth, gonadal histology, parasites, feeding habits and trophic niches as well as ecological relationships among species.

The diversity of ichthyofuana on the continental shelf of this zone is also quite high, with 158 species representing 97 genera and 72 families. Senior research involved with the ecology of the nearshore coastal ichthyofauna includes feeding patterns and partitioning food resources among trophic guilds, seasonal changes in the most species rich families, such as Sciaenidae and Triglidae, and studies of the shrimp by-catch.

The fundamental importance of these senior theses is the link they make between teaching and hands-on research, which is an important part of the student's academic preparation. The completion of senior research theses has resulted in students that understand biology as it is related to local fisheries in both the Tecolutla River and the Alvarado lagoonal system.

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Trophic Comparison of Two Species of Needlefish (Belonidae) in the Alvarado Lagoonal System, Veracruz, Mexico

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TROPHIC COMPARISON OF TWO SPECIES OF NEEDLEFISH (BELONIDAE) IN THE ALVARADO LAGOONAL SYSTEM, VERACRUZ, MEXICO

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ABSTRACT We compared the diets of Atlantic needlefish, *Strongylura marina*, and redfin needlefish, *Strongylura notata*, in the Alvarado lagoonal system, Veracruz, Mexico, and analyzed diet breadth and trophic overlap between the species. All fishes were collected monthly from June 2000 to July 2001 at twelve sampling stations. A total of 74 intestinal tracts from *S. marina* were analyzed. The diet of *S. marina* consisted of 25 prey types with fish being the dominate prey. In eighty-nine digestive tracts examined from *S. notata*, the diet consisted of 29 prey types with the dominant prey including fishes, penaeid shrimp, polychaetes, and hymenopteran insects. There was moderate diet overlap ($\alpha = 0.4903$) between *S. marina* and *S. notata* in the rainy season, while there was little diet overlap between species during the "nortes" ($\alpha = 0.1037$) or dry ($\alpha = 0.1675$) season. There was reduced niche breadth in both *S. marina* and *S. notata* during the "nortes" ($B_A = 0.175$ and 0.105, respectively) and dry ($B_A = 0.128$ and 0.173, respectively) seasons, with niche breadth values being higher for both species during the rainy season ($B_A = 0.254$ and 0.296, respectively).

RESUMEN Se realizó una comparación de la dieta de los belonidos, *Strongylura marina* y *Strongylura notata*, en el sistema lagunar de Alvarado, Veracruz, México, analizando la amplitud de dieta y el solapamiento trófico de ambas especies. Los organismos se colectaron mensualmente en el período de junio de 2000 a julio de 2001 en 12 estaciones de muestreo. Se analizaron 74 tractos digestivos de *S. marina*. La dieta de *S. marina* consiste de 25 tipos de presa de los cuales los peces constituyeron la presa dominante. Para *S. notata* se analizaron 89 tractos digestivos, la dieta de esta especie comprendió 29 tipos de presas diferentes, siendo los peces, camarón, poliquetos e himenópteros las presas dominantes para esta especie. El solapamiento trófico entre *S. marina* y *S. notata* fue moderado ($\alpha = 0.4903$) en la época de lluvias, disminuyendo en las épocas de nortes ($\alpha = 0.1037$) y secas ($\alpha = 0.1675$). La amplitud del nicho trófico para *S. marina* y *S. notata* fue baja en nortes ($B_A = 0.175$ y 0.105, respectivamente) y en secas ($B_A = 0.128$ y 0.173, respectivamente), siendo mayor para ambas especies en la época de lluvias ($B_A = 0.254$ y 0.296, respectivamente).

INTRODUCTION

The eastern coast of Mexico consists of a series of estuarine lagoons that have recently been studied in relation to their ichthyofauna. Most studies focus on specific habitat types like mangroves (Gonzales 1995) and seagrass beds (Latisnere and Moranchel 1983, Solano 1991, Benavides 1996, Chavez-López 1998), or on general aspects of fisheries ecology (Castillo 1995), including selected trophic studies (Yañez-Arancibia 1978, Salgado 1997). Nevertheless, little work has been done with needlefishes (family Belonidae) in Mexico despite the ecological importance of this family in coastal lagoons.

The Belonidae are represented globally by 32 species in 10 genera. Belonids are rarely exploited by man, although there is a recreational fishery in Mexico (Torres-Orozco 1991), with consumption restricted to local areas where the fishes reach large sizes (Zeckua and Martinez-Perez 1993). The genus *Strongylura* occurs in the coastal

lagoons of Mexico and is also found in oceanic and nearshore waters worldwide (Goulding and Carvalho 1984). Zeckua and Martinez-Perez (1993) studied the ontogenetic development of *Strongylura marina* in the estuary of Tecolutla, Veracruz. However, trophic relationships are unknown in these coastal lagoons. Understanding belonid feeding habits is important in establishing the functional role of these species in the ecosystem. Adult and juvenile needlefish are known to be piscivorous (Reid 1954, Springer and Woodburn 1960, Carr and Adams 1973), but trophic overlap in *Strongylura* has not been examined. Thus, the objective of this work was 1) to compare the diets of the Atlantic needlefish, *S. marina* (Walbaum, 1792), and the redfin needlefish, *Strongylura notata* (Poey, 1860), in the Alvarado lagoonal system, Veracruz, Mexico and 2) to analyze their diet breadths and trophic overlaps.
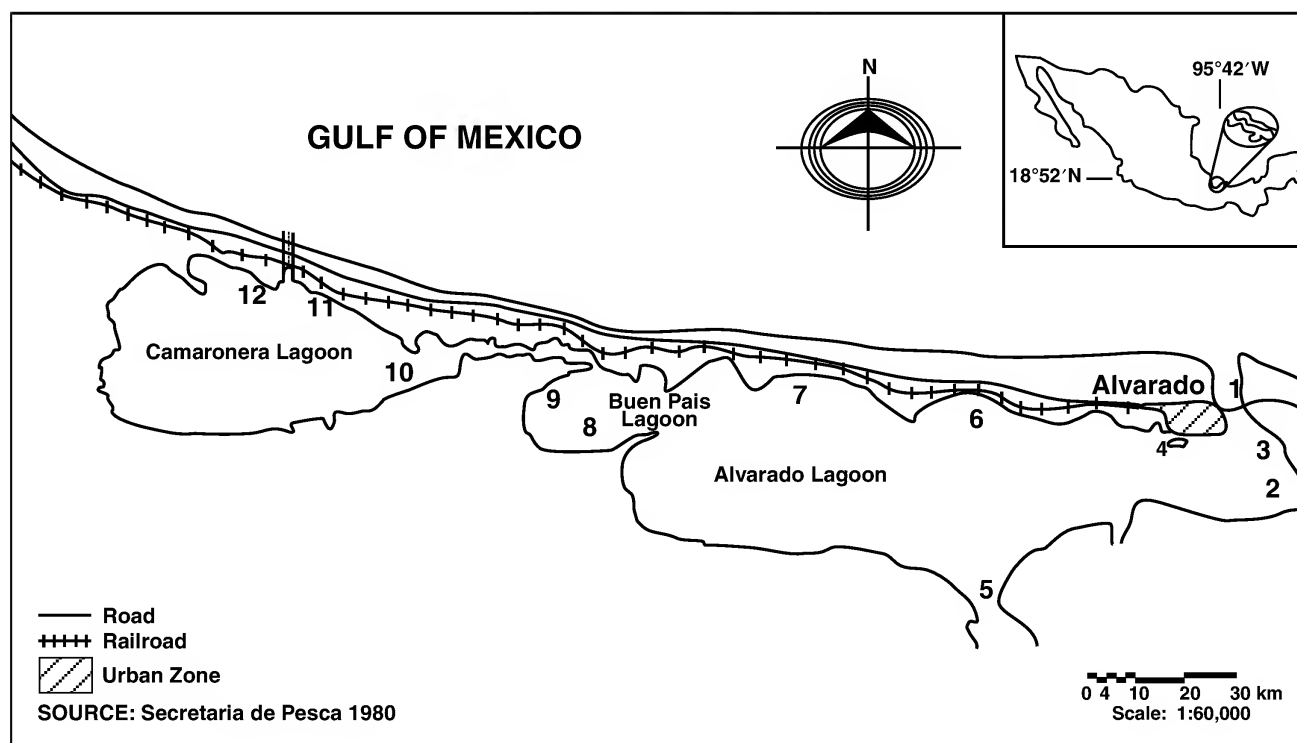
Figure 1. Collection stations in the Alvarado lagoonal system, Veracruz, Mexico.

MATERIALS AND METHODS

Study area

The Alvarado lagoonal system (Figure 1) is located in the southeast portion of Veracruz State in the Papaloapan basin, between 18°52'15"N, 95°57'32"W and 18°23'00"N, 95°42'20"W. Camaronera, Buen Pais, and Alvarado Lagoons are connected by channels and the system is about 26 km long and 5 km wide, with a total area of 6200 ha. The mean annual water temperature oscillates between 25.6 °C and 26.1 °C and the mean annual precipitation is 212.1 cm (Chavez-López 1998). Seasons are well defined, with the rainy season from June to September, the nortes season from October through February (occassionally extending until May), and the dry season from March through June (Contreras 1985). The lagoonal system is almost entirely surrounded by red mangrove (*Rhizophora mangle* L.) and is bordered by a landward zone of black mangrove (*Avicennia germinans* L.) and white mangrove (*Laguncularia racemosa* (L.) Gaertn. f.). Other emergent vegetation includes cordgrass (*Spartina* spp.) and cattail (*Typha* spp.) (Resendez 1973), with the shallow, muddy bottom containing large patches of Widgeon grass (*Ruppia maritima* L.). During the rainy season, the water hyacinth (*Eichomia crassipes* (Mart.) Solms.) enters the lagoon from the upstream watershed.

Field procedures

All fishes and physical-chemical variables were collected monthly from June 2000 to July 2001 at twelve sampling stations. These stations represented seagrass, mangrove, shell reef, and muddy bottom habitat types. Samples were taken with a beach seine (40 m long, 1.5 m high, 6.3 mm mesh), and digestive tracts were fixed in the field by injecting 39% formaldehyde into the coelomic cavity to stop the digestive process. Samples were then placed in plastic bags containing 4% formalin or 70% alcohol. At each station, salinity (psu) was measured with a YSI model 33 salinometer, dissolved oxygen (D.O., mg/L) was measured with an Otterbine Sentry III oxygen meter, and water temperature (°C) was obtained with a mercury thermometer.

Laboratory and statistical procedures

In the laboratory, fishes were rinsed with tap water, preserved in 70% alcohol, and identified (Alvarez del Villar 1970, Hoese and Moore 1977, Fischer 1978, Castro-Aguirre 1978, Castro-Aguirre et al. 1999). Preserved standard length (SL, cm) and wet mass (g) were taken, and the fishes were divided into 8 size classes (cm): I = 3.0–9.0, II = 9.1–15.0, III = 15.1–21.0, IV = 21.1–27.0, V = 27.1–33.0, VI = 33.1–39.0, VII = 39.1 45.0, and VIII = 45.1–51.0.

TABLE 1

Summary of seasonal minimum, maximum, and mean physico-chemical variables in the Alvarado lagoonal system from June 2000–July 2001. D.O. = dissolved oxygen.

	Rainy Season			Nortes Season			Dry Season		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature (°C)	22.0	32.0	30.0	21.0	32.0	25.0	27.0	30.0	27.0
Salinity (psu)	0.0	21.0	4.9	0.0	11.5	4.0	2.5	35.0	10.4
D.O. (mg/L)	2.4	14.4	10.8	8.0	12.3	9.8	8.0	12.2	9.5

The entire digestive tract from the esophagus immediately behind the branchial cavity to the anus was examined, and only digestive tracts containing identifiable prey types were used in the analysis. Prey was identified to the lowest possible taxonomic level and then grouped into fishes, crustaceans, insects, annelids, and others for analysis. Numeric (percentage of all prey types), gravimetric (percentage of the total mass of all prey items), and frequency of occurrence (percentage of digestive tracts in which one or more prey types were present) were documented. These measurements were incorporated into a percent Index of Relative Importance (%IRI; Cortez 1997) to determine the most important prey for these predator species. Schoener's index, α (Schoener 1970, Wallace 1981), was used to assess dietary overlap, where α approaches 0 when diets do not contain items in common, and α approaches 1 with high similarity between diets. Niche breadth was calculated using Levin's standardized index, B_A (Krebs 1989), where values of B range from 0 to 1 and low values indicate diet specialization because of the dominance by a few prey types.

RESULTS

Field collections

In the Alvarado lagoon system, the highest temperature and D.O. concentration occurred during the rainy season, with the lowest temperature and salinity noted during the "nortes" season. The highest salinity and the greatest salinity range were observed during the dry season (Table 1). The 3 lagoons also differed seasonally in relation to salinity. Camaronera generally had higher salinity, followed by Buen Pais, with Alvarado fluctuating between near 0 to 35 psu during the dry season (Figure 2).

The family Belonidae was represented by 3 species in the lagoon; *S. marina*, *S. notata*, and *Strongylura timucu* (Walbaum, 1792). Of 195 belonids captured, *S. notata* represented 53% of the total and *S. marina* represented 46%. *Strongylura timucu* accounted for only 1% of the total. Peak abundance of *S. notata* occurred in the low salinity "nortes" season; in contrast, *S. marina* was found predominantly in the high salinity dry season.

Size and seasonal abundance

All sizes of *S. marina* except class IV (21.1–27.0 cm) were collected in the rainy season, with size class II and III (9.0–21.0 cm) being most abundant. During the "nortes" season, size classes I, II, III, V and VII were taken in equal abundance. Dry season collections had all size classes, with small individuals (3–15 cm, classes I and II) being most abundant (Figure 3). In contrast, all size classes of *S. notata* except VIII were collected during the rainy season, with individuals in classes II and III dominating the catch.
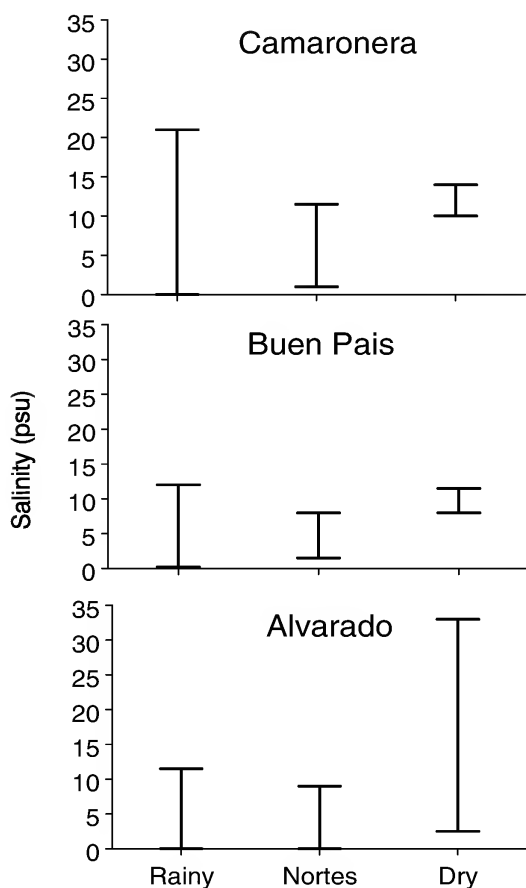
Figure 2. Minimum and maximum salinity values by lagoon and season within the Alvarado lagoonal system, Veracruz, Mexico.

TABLE 2

Seasonal %IRI of each prey item in the diet of *S. marina* and *S. notata* collected from June 2000–July 2001.

Taxa	*S. marina*			*S. notata*		
	Rainy	**Nortes**	**Dry**	**Rainy**	**Nortes**	**Dry**
Pisces						
Unidentified Fishes	61.12	82.28	82.74	60.40	11.93	52.73
Engraulidae	3.32	10.98	3.18			
Mugilidae			< 1			
Mugil curema					< 1	
Cichlidae				< 1		
Syngnathidae		< 1			< 1	
Belonidae						2.46
Hemiramphidae		< 1				
Larval fish		< 1		< 1	1.61	
Crustaceans						
Unidentified crustaceans	2.63	< 1			1.63	< 1
Penaeidae	15.56			6.49	53.98	
Litopenaeus setiferus			7.55			
Farfantepenaeus aztecus					2.79	
Palaemonetes pugio					< 1	
Macrobrachium spp.				1.62	< 1	14.10
Callinectes spp.			< 1		< 1	
Portunidae	1.27					
Amphipoda	< 1	< 1	< 1		< 1	3.87
Anomura (Albunea)					< 1	
Brachiura					< 1	
Caridea						< 1
Insects						
Unidentified Insects	< 1		< 1	3.94	1.44	
Hymenoptera parts			< 1		3.19	1.59
Hymenoptera (wasps)	13.41		1.70	20.31	< 1	< 1
Hymenoptera (bees)			< 1			
Formicidae	< 1	1.29	< 1	< 1	10.67	6.79
Diptera			< 1	< 1	7.69	1.42
Coleoptera	< 1	2.48	1.07	< 1		< 1
Coleoptera (Curculionidae)				< 1	< 1	< 1
Odonata				< 1	< 1	
Libellullidae			< 1			
Hemiptera	< 1		< 1		1.05	
Phasmidae				< 1		
Isoptera			< 1			
Homoptera					< 1	
Annelida						
Unidentified polychaetes	< 1	< 1	< 1	4.74	< 1	14.79
Others						
Chelicerata		< 1				
Seagrass	< 1					
Unidentified organic matter				< 1	< 1	
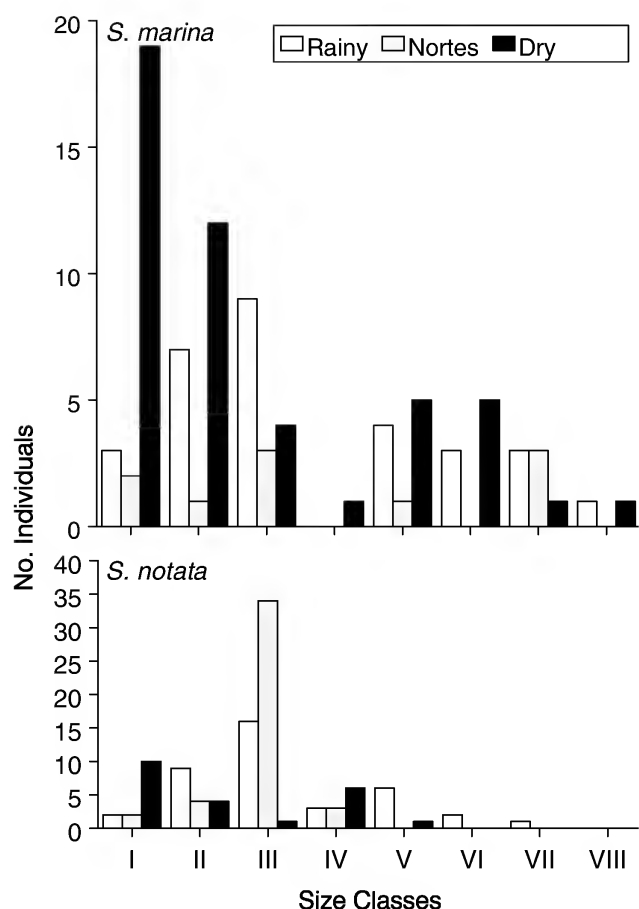
Figure 3. Abundance of S. marina and S. notata by size class in the Alvarado lagoon system, Veracruz, Mexico.

Only fish in classes I to IV were captured during the "nortes" season, although most were in the 15.1–21.0 cm range (class III). During the dry season, fish in classes I to V were captured, but the smallest fish (3–9 cm, class I) were most abundant (Figure 3).

General feeding habits

A total of 74 intestinal tracts from *S. marina* were analyzed with 24 from the rainy season, 7 from the "nortes" season, and 43 from the dry season. The diet of *S. marina* consisted of 25 prey types (Table 2). Fishes dominated the diet in all seasons (61–82.7 %IRI; Table 2) with penaeid shrimp (15.6 %IRI) and wasps (13.4 %IRI) also being important in the rainy season, engraulids (10.9 %IRI) being important in the "nortes" season, and the white shrimp, *Litopenaeus setiferus* (7.5 %IRI), being important in the dry season. There did not appear to be an ontogenetic shift in prey types, as fish > 5 cm SL included insects, crustaceans, and polychaetes within their diet.

Eightly-nine intestinal tracts from *S. notata* were examined with 28 from the rainy season, 41 from the

"nortes" season, and 20 from the dry season. The diet of *S. notata* contained 29 prey types with the dominant prey including fishes, penaeid shrimp, polychaetes, and wasps (Table 2). Fishes dominated the diet in the rainy and dry season (52.7–60.4 %IRI; Table 2) with penaeid shrimp being most important (53.9 %IRI) in the "nortes" season. In the rainy season, wasps (20.3 %IRI) and penaeid shrimp (6.49 %IRI) were also important, whereas in the "nortes" season several orders of insects (Formicidae 10.7 %IRI, Diptera 7.7 %IRI) and fishes (11.9 %IRI) were important. Finally, polychaetes (14.8 %IRI), *Macrobrachium* spp. (14.1 %IRI) and Formicidae (6.8 %IRI) were also important prey items in the dry season. As with *S. marina*, there did not appear to be an ontogenetic shift in prey categories, with fish of all size classes equally likely to consume all prey types.

Rainy season

In Alvarado Lagoon, *S. marina* of size classes I and VIII fed exclusively on fishes. In contrast, individuals in size classes II and III fed on crustaceans and insects, whereas those in size class VI fed principally on crustaceans. Feeding was quite different in Camaronera Lagoon, with fish < 20 cm having a varied diet of fishes, wasps, and crustaceans, while larger fish (size class VII) consumed polychaetes exclusively.

Strongylura notata were collected from all 3 lagoons during the rainy season. In Alvarado Lagoon, size classes I and II fed mainly on fishes, whereas slightly larger individuals (size class III) ate mostly fishes and *Macrobrachium*. Size class VII ate exclusively insects. In Buen Pais Lagoon, size class I fed on fishes (65 %IRI) and wasps, size class II individuals consumed insects (principally odonatids and dipterans), and size classes III and IV fed exclusively on insects, primarily wasps. In Camaronera Lagoon, size class I ate predominately wasps and penaeid shrimp, whereas fish dominated the diet of individuals in size classes III–V, and wasps were the principal prey type of size class VI.

Nortes season

Strongylura marina was found in Alvarado Lagoon only during the "nortes" season. Size class I individuals fed on fishes and crustaceans, size class II individuals ate fishes, Formicidae and coleopteran insects, while size class VII fed on engraulids. During the "nortes" season, *S. notata* was captured only in Camaronera Lagoon, and the smallest individuals (size classes I and II) were primarily piscivorous. Larger individuals added penaeid shrimp (size class III) and dipterans (size class IV) to their diet.

Dry season

In Alvarado Lagoon, a wide variety of predator sizes and prey items were found. Size classes I and II *S. marina* fed principally on fishes. As they increased in size (size classes III–IV), the diet became more varied, including crustaceans and insects (primarily hymenopterans). Fish in size class V consumed predominantly engraulids (38.4%) along with other fishes, whereas the largest predators (size class VIII) ate fishes and insects. In Buen Pais Lagoon, size class I fed on amphipods, individuals in size class V ate polychaetes, those in size class VI fed on polychaetes and wasps, and the largest (size class VII) were piscivorous. In Camaronera Lagoon, the principal prey items in size classes II and VI were engraulids, whereas polychaetes were the predominate prey in size class V.

Strongylura notata were collected from all 3 lagoons during the dry season. In Alvarado Lagoon, size class I ate hymenopteran insects exclusively, whereas individuals in size class II ate fishes and Formicidae. The largest predators (size class IV) had a more varied diet, consisting of fishes, *Macrobrachium*, amphipods and dipterans. In Buen Pais Lagoon, only the smallest size class was collected, and they fed principally on fishes. A wide range of size classes was collected in Camaronera Lagoon. The smallest ate amphipods (60 %IRI), fishes (19 %IRI) and *Palaemonetes pugio* Holthuis, 1949 (20 %IRI). Predators in size class II had a diet of < 90 %IRI polychaetes, whereas size class III exclusively ate insects from the coleopteran family. Larger individuals (size class IV) had a diet consisting of fishes (including belonids) and *Macrobrachium*, while the largest (V) fed primarily on polychaetes with a small component of fishes and formacid insects.

Diet overlap and niche breadth

There was a moderate diet overlap ($\alpha = 0.4903$) between *S. marina* and *S. notata* in the rainy season. In contrast, there was little diet overlap between species during the "nortes" ($\alpha = 0.1037$) or dry ($\alpha = 0.1675$) season. There was reduced niche breadth in both *S. marina* and *S. notata* during the "nortes" ($B_A = 0.175$ and 0.105, respectively) and dry ($B_A = 0.128$ and 0.173, respectively) seasons, suggesting specialization due to the presence of few prey types. In contrast, niche breadth values were twice as high for both species during the rainy season ($B_A = 0.254$ and 0.296, respectively), suggesting a more generalist approach to feeding.

DISCUSSION

Salinity varied seasonally in the Alvarado lagoonal system. In the rainy season, low salinity conditions were present as a consequence of increased river discharge from the Blanco, Acula, and Papaloapan rivers. During the "nortes" season, salinity was low (approaching 0 psu) due to strong wind-driven circulation. In contrast, the salinity in the system increased during the dry season, as river discharge slowed and salt water entered the lagoon from the inlets.

The diets of *S. marina* and *S. notata* were dominated by fishes, crustaceans, polychaetes, and insects. *Strongylura marina* fed principally on fishes from the families Engraulidae, Mugilidae, Hemiramphidae, and Syngnathidae. Previously, *S. marina* has been reported to be voracious, principally consuming small pelagic fishes such as anchovies and sardines (Castro-Aguirre et al. 1999). Crustaceans were of secondary importance to *S. marina* and included such prey items as penaeid and caridean shrimp, amphipods, and portunid crabs (predominantly *Callinectes*). Insects (primarily hymenopterans) also occupied an important place in their diet. Franke and Acero (1992) reported wasps in the stomach contents of belonids, along with other insects such as coleopterans, odonterans, dipterans, hemipterans, and isopterans. The insect component of the diet was most important during the rainy season, when the salinity of the lagoonal system was low and there was high discharge from the rivers into the lagoon. This probably contributes to the increased availability of insects. During both the "nortes" and dry seasons, fishes were most important in the diets. *Strongulura marina* juveniles have been found to feed on small crustaceans, specifically amphipods, mysids and smaller shrimp, with an abrupt transition to a diet almost exclusively of fishes at about 5.0 cm TL (Carr and Adams 1973). However, in the present study *S. marina* > 5.0 cm had a more varied diet. Although occasionally the diet was piscivorous, consuming principally engraulids, the larger individuals at times ingested only insects or included crustaceans, polychaetes, and insects in their diet. The suite of prey in the diet of *S. marina* appeared to vary among the 3 basins within a given season. This may be related to the salinity differences among basins due to differing levels of freshwater input.

Fishes from the families Belonidae, Syngnathidae, Mugilidae, and Cichlidae were the major components in the diet of *S. notata*. This species also fed on different types of crustaceans such as *Macrobrachium* spp., *Callinectes* spp., *P. pugio*, penaeid shrimp, *Farfantepenaeus aztecus* Ives, 1891, amphipods, brachyurans, and anomurans. Other items that formed a part of the diet included polychaetes and insects such as hymenopterans, dipterans, phasmids, odonatids, and coleopterans. Our findings agree with previous reports that fishes and insects

dominate the diet of *S. notata* (Ley et al. 1994). Insects were important during the rainy and the dry seasons, whereas crustaceans dominated the diet during the "nortes" season. Similarly, Chavez-López (1998) mentioned that *S. notata* complemented its fish diet with crustaceans during the "nortes" season, whereas complementary prey during the rainy and dry seasons were the hymenopterans and dipterans. In the present study, there was no diet transition observed in *S. notata* associated with body size. Indeed, the lack of specific prey types as related to size was more evident in *S. notata* than in *S. marina*, as the former species actively fed in the water column.

The variety in the diets of the *Strongylura* species may also be related to their feeding behavior. Belonids have been observed to capture prey in different ways, such as attacking benthic prey, catching fishes swimming at the surface, or jumping out of the water to capture insects in mangroves (Ley et al. 1994). Both *S. marina* and *S. notata* feed throughout the water column, as demonstrated by both the demersal and pelagic components of the diet.

Clearly, the diet of these 2 predators is variable spatially and temporally, which can be due to variation in prey availability and/or the level of prey identification in the diet. Prey availability varies, in part, due to different environmental conditions within the lagoon system which are driven by seasonal weather patterns and landscape factors. These seasonal weather patterns characterize the environment of the Alvarado lagoonal system. As both species appear to be opportunistic predators with only little to moderate diet overlap and a low niche breadth during the dry and "nortes" seasons, it follows that their diets will change spatially and temporally as river discharge, tidal flushing, rainfall, and salinity change.

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Feeding Habits and Sexual Dimorphism of the Violet Goby, *Gobioides broussoneti* Lacepede (Pisces: Gobiidae), in the Estuarine System of Tecolutla, Veracruz, Mexico

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FEEDING HABITS AND SEXUAL DIMORPHISM OF THE VIOLET GOBY, *GOBIOIDES BROUSSONETI* LACEPEDE (PISCES: GOBIIDAE), IN THE ESTUARINE SYSTEM OF TECOLUTLA, VERACRUZ, MEXICO

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ABSTRACT Gobioides broussoneti were sampled in Silveña estuary, a branch of the Tecolutla estuary, Veracruz, Mexico, during 2 trips made between February 1998 and June 1999 to evaluate diet and sexual dimorphism. A total of 65 *G. broussoneti* ranging from 49–401 mm SL (0.7–124.2 g WW) were collected. There was a 1:1.2 sex ratio in favor of females. Seven food types were noted, with filamentous algae (25.4%) and detritus (21.3%) representing the principal food types. A 24 h feeding study revealed that this species feeds continuously throughout the day. The ovaries of all female *G. broussoneti* contained previtellogenic oocytes, characteristic of immature or regressed fish. In contrast, the lobular testis of the males contained late stages of spermatogenesis, suggesting that the fish examined were at the end of the reproductive season. Sexual dimorphism of *G. broussoneti* is distinguished by a small urogenital papilla, which is in the ventral region between the anal orifice and the anal fin origin. In the females it is short, blunt and has a yellow coloration; in males it is thin, pointed and has a smooth appearance. Only immature or regressed females were captured during this study indicating that *G. broussoneti* uses the Tecolutla estuary as a nursery and feeding ground. Questions about reproductive seasonality, ovarian development, and spawning of *G. broussoneti* need further investigation.

RESUMEN Gobioides broussoneti fue muestreado en el estuario Silveña, un brazo del estuario Tecolutla, Veracruz, México, durante 7 muestreos realizados entre febrero de 1998 y junio de 1999, para evaluar la dieta y el dimorfismo sexual. Fueron colectados un total de 65 *G. broussoneti* con tallas de 49–401 mm de longitud estándar y peso entre 0.7 y 124.2 g. Presentaron una proporción sexual de 1:1.2 a favor de las hembras. Siete tipos alimenticios fueron registrados; las algas filamentosas (25.4 %) y el detritus (21.3 %) representan los principales tipos alimenticios; un estudio alimenticio de 24 horas reveló que esta especie se alimenta continuamente a lo largo del día. Los ovarios de todas las hembras de *G. broussoneti* contienen ovocitos previtelogénicos, característicos de peces inmaduros o regresados. En contraste, el testículo lobular de los machos contenía estadios tardíos de la espermatogénesis, sugiriendo que el pez examinado se encontraba al final de la estación reproductiva. El dimorfismo sexual de *G. broussoneti* se distingue por una pequeña papila urogenital, que se encuentra en la región ventral, entre el orificio anal y el origen de la aleta anal. En las hembras esta es corta, achatada y de coloración amarilla; en machos es delgada, afilada y tiene una apariencia lisa. Estos resultados indican que *G. broussoneti* utiliza el estuario de Tecolutla como un lugar de crianza y alimentación, ya que en este estudio solo fueron capturadas hembras inmaduras o regresadas. Cuestionamientos acerca de estacionalidad reproductiva, desarrollo ovárico y desove de *G. broussoneti* requieren mayor investigación.

INTRODUCTION

Members of the Gobiidae are small benthic fishes inhabiting a wide range of habitats in temperate and tropical regions (Dawson 1969, Iglesias 1981, Nelson 1994) and are characteristically secretive and more abundant than generally noted (Hendon et al. 2000). Gobiids are one of the most abundant group of species in marsh-edge habitats in the Gulf of Mexico (Baltz et al. 1998, Hendon et al. 2000) and presumably play an important role in the ecology of coastal environments. They also contribute to the food web in many estuarine and marine environments (Maciolek 1981, Nelson et al. 1992).

The violet goby, *Gobioides broussoneti*, is a larger member of the Gobiidae and is distributed from the western Atlantic of the United States to Rio de Janeiro, Brazil,

including the Gulf of Mexico, and the Caribbean coast along Colombia, Venezuela and French Guyana (Greenfield and Thomerson 1997, Murdy 1998, Hoese and Moore 1998). It typically occurs in marine and estuarine environments (Castro-Aguirre 1978, Hoese and Moore 1998) but has been found in fresh water (Hubbs et al. 1991). Little data are available on the ecology and life history of this species, with the exceptions of systematic (Pezold 1993, Murdy 1998), cytogenetic (Aguirre and Nader 1987), and aquarium care and maintenance studies (Brackish Water Aquaria FAQ 2003, Fishbase 2003). Given the lack of much biological or ecological data on this species (Darcy 1980, Fishbase 2003), the objective of this work is to document the feeding habits and sexual dimorphism of *G. broussoneti* in the estuarine system of Tecolutla, Veracruz, Mexico.

MATERIALS AND METHODS

Field sampling

Fish were sampled in Silveña estuary, a branch of the Tecolutla estuary, Veracruz, Mexico, with a beach seine (30 m long by 1.5 m high, 12.7 mm mesh) during 7 trips made between February 1998 and June 1999. All fish were placed in 20 L buckets, and transported to a provisional laboratory where they were sacrificed, weighed (g), measured for standard length (SL, mm), and preserved in 10% formalin. During the March 1999 trip, fish were sampled every 4 h over a 24 h period to estimate feeding periodicity.

Laboratory procedures

In the laboratory, fish were rinsed overnight in running tap water, and the entire digestive tract was removed from each individual and placed in petri dishes with distilled water to avoid desiccation. The food items were separated with the use of a Nikon model SMZ-1 stereomicroscope and a Nikon optic microscope. Food items were identified to the lowest taxonomic level possible, following Sanchez and Ponce (1996). The frequency of occurrence of each food type was estimated (Hyslop 1980), and the diet of the fish collected during the 24 h study was expressed on a qualitative scale (Prejs and Colomine 1981). This was done using a combination of food quantity and its distribution in the digestive tract (stomach vs. intestine) to estimate when the fish last fed, with 0 = empty, 1 = minimal food, 2 = scarce food, 3 = medium food, 4 = full, not bulging, and 5 = full and bulging.

To document sexual dimorphism, a macroscopic description of the female and male reproductive apparatus was made. The gonads and urogenital papilla were removed from the fish, dehydrated, and embedded in paraffin following standard histological techniques. Tissue was sectioned at 5–7μm and stained with hematoxylin and eosin.

RESULTS AND DISCUSSION

A total of 65 *G. broussoneti* (36 females, 29 males) were collected, ranging from 49–401 mm SL and 0.7–124.2 g wet weight. The sex ratio was 1:1.2 in favor of females. *Gobioides broussoneti* was collected only over muddy bottoms in highly turbid areas adjacent to seagrass beds.

Feeding habits

Of the total of 65 digestive tracts examined, only 4 (6.1%) were empty. Seven food types were determined with filamentous algae (25.4%) and detritus (21.3%) representing the principal food types. These food types were followed in occurrence by copepods (17.6%), bivalves (11.9%), foraminiferans (9.4%), eggs (9.0%) and gastropods (5.3%) (Figure 1).

Gobioides broussoneti can be classified as a primary consumer (Yañez-Arancibia and Nugent 1977) as the diet generally consisted of detritus and filamentous algae. This is supported by the presence of a long, folded alimentary canal, a defining characteristic of herbivorous species (Horn 1989). The presence of copepods, bivalves, foraminiforans, eggs and micro-mollusks in the diet, although showing a relatively high frequency of occurrence, appears to be incidental. The violet goby feeds on colonies of benthic algae and can incidentally ingest large quantities of detritus and related organisms from this feeding habit (Brackish Water Aquaria FAQ 2003). The diets of many goby species also indicate that detritus and algae are common food types (Kinch 1979, Darcy 1980, 1981, Maciolek 1981).

Sixteen violet gobies were collected during the 24 h study, ranging in size from 121–227 mm SL and 7.8 to 45.3 g. Eleven contained food in the stomach and intestine, whereas 5 had a small quantity of food in the stomach but had a full intestine (Table 1), with no variation in food type based on size. Although diel variation in stomach fullness is common in fishes (Grossman et al. 1980, Wootton 1990), the majority (69%) of *G. broussoneti* sampled had full stomachs and/or intestines, regardless of the time of day (Table 1).
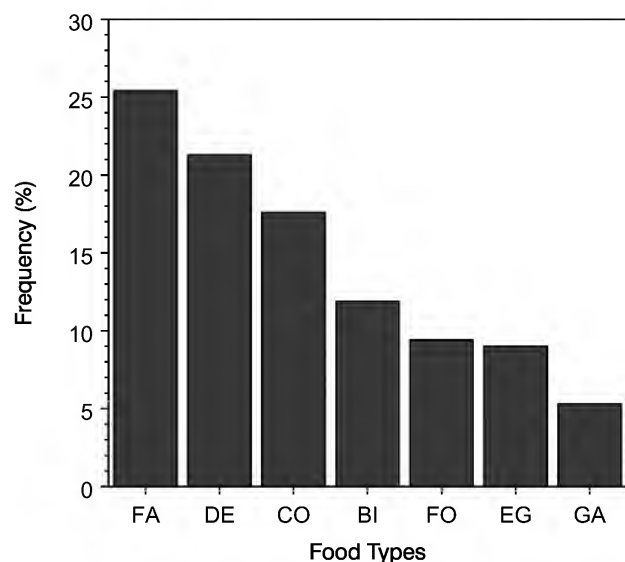

Figure 1. Frequency of occurrence of food types of *Gobioides broussoneti* (*n* = 65) from February 1998 to June 1999 in the estuarine system of Tecolutla, Veracruz. FA = filamentous algae, DE = detritus, CO = copepods, BI = bivalves, FO = foraminifera, EG = eggs, and GA = gastropods.

TABLE 1

Food distribution in the digestive tracts of *Gobioides broussoneti* over a 24 h cycle. S = stomach, I = intestine. Numbers in parentheses refer to qualitative scale. 0 = empty to 5 = maximally full.

Collection time	Number of fish	Food distribution in digestive tract
1530	6	S and I (4) (3 fish)
		S (1), I (4) (3 fish)
1930	0	—
2330	2	S and I (4) (2 fish)
0330	3	S and I (4) (2 fish)
		S(1), I (4) (1 fish)
0730	1	S and I (4)
1130	4	S and I (4) (3 fish)
		S (1), I (4) (1 fish)
1530	0	—

Sexual dimophism

The ovaries of all female *G. broussoneti* examined for this study contained previtellogenic oocytes, characteristic of immature or regressed fish. In contrast, the lobular testis of the males contained several stages of spermatogenesis, including spermatids and spermatozoa. The lumen of the lobules was partially empty of spermatozoa, and there was little evidence of active spermatogenesis, suggesting that the fish examined were at the end of the reproductive season (Brown-Peterson et al. 2002). These results indicate that *G. broussoneti* uses the Tecolutla estuary as a nursery and feeding ground, as only immature or regressed females were captured during this study. Violet gobies have been reported to reach up to 553 mm TL and 311 g (Fowler 1947, Fishbase 2003), much larger than most females captured during this study. This suggests that *G. broussoneti* spawns in the open ocean and should be considered a tem-

poral species from Tecolutla estuary. The capture of males in late stages of the reproductive cycle, with minimal spermatogenesis, confirms that the fish may move into the estuary to feed once spawning is completed offshore.

The sexes of *G. broussoneti*, as in the majority of the gobiids, are easily distinguished by the form of the urogenital papilla, which is in the ventral region between the anal orifice and the anal fin origin. In the females it is short, blunt, and yellow; in males it is thin, pointed, and has a smooth appearance. In both sexes, the urogenital papilla is covered only by epithelium and not by scales. In a transverse histological section, the female papilla has a thin layer of flat stratified epithelium, a network of capillaries, and a thick layer of muscular fiber. At the center are 2 different orifices. The larger opening is the oviduct, which is elongated and has evaginations of cylindrical epithelium. The urinary duct is smaller and has a lobular-shaped aperture of simple cubic epithelium (Figure 2A). In males, a transverse histological section of the papilla shows a layer of flat simple epithelium and a layer of connective tissue surrounding a capillary net. There are 2 openings at the center of the section. The large genital duct has an irregular, flower-like opening formed by a layer of cylindrical epithelium, whereas the small urinary duct has an oval aperture which is comprised of simple cubic epithelium (Figure 2B).

The histology of the urogenital papilla in both sexes revealed thick layers of muscular fibers, which suggest a contractile power by the females for ovulation and ovopositioning (Tavolga 1954, Miller 1984). In the males, the papilla functions as an erected organ to fulfill diverse functions such as courtship, secretion of chemical substance in the spawning area, and to help direct the sperm flow (Hoffman 1963, Bianco et al. 1987).
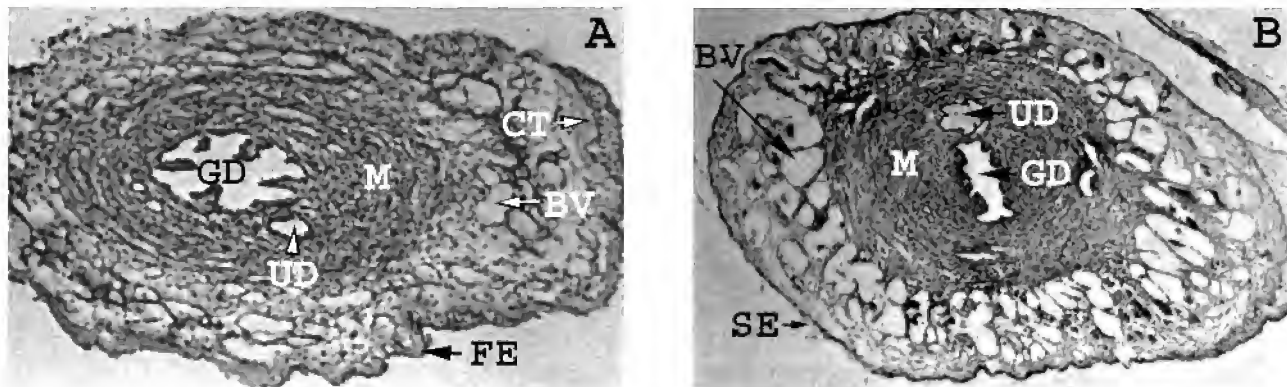

Figure 2. Transverse sections of the urogenital papilla of *Gobioides broussoneti*. A) Female. Present are a layer of flat stratified epithelium (SE), blood vessels (BV), musculature (M), urinary duct (UD) and genital duct (GD), 80x, H-E. B) Male. Simple flat epithelium (FE), connective tissue (CT), blood vessels (BV), musculature (M), genital duct (GD) and urinary duct (UD), 80x, H-E.

In conclusion, we have determined that *G. brossoneti* is a temporal resident in the estuarine system of Tecolutla, Veracruz, apparently using the estuary as a feeding and nursery ground. This fish is a primary consumer and feeds principally on algae at all times of the day, with no distinctive feeding period. Finally, the sex of *G. broussoneti* individuals can be determined by the urogenital papilla. Questions that remain to be answered include those concerning reproductive seasonality, ovarian development, and spawning of *G. broussoneti* within the Tecolutla estuarine system and adjacent offshore waters.

ACKNOWLEDGMENTS

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Gonadal Development and Sexual Dimorphism of *Gobiomorus dormitor* from the Estuarine System of Tecolutla, Veracruz, Mexico

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GONADAL DEVELOPMENT AND SEXUAL DIMORPHISM OF *GOBIOMORUS DORMITOR* FROM THE ESTUARINE SYSTEM OF TECOLUTLA, VERACRUZ, MEXICO

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ABSTRACT The bigmouth sleeper, *Gobiomorus dormitor*, is a benthic, euryhaline species, and is very abundant in river mouths, coastal lagoons, and sites away from marine influence from south Florida to Dutch Guyana. There are few studies of its life history, ecology, and abundance, particularly within Mexican waters. Nine trips to Tecolutla estuary, Veracruz, Mexico, were taken between October 1995 and May 1998 to estimate the gonadal development and sexual dimorphism of *G. dormitor*. A total of 94 individuals ranging from 15–260 mm SL and 0.05–181 g were captured. Seventy-two specimens were adults (60 females, 12 males) and 22 were juveniles that did not show external sexual dimorphism. Both juvenile and adult stages of *G. dormitor* were captured year-round in seagrass beds and adjacent shallow, muddy or sandy areas. This study has shown that *G. dormitor* are resident and undergo sexual maturation in the Tecolutla estuary. Histological evidence suggests both males and females undergo gonadal recrudescence in the estuary and have an extended reproductive season from May through November. However, it is unclear if the species actually spawns in the estuary, since females in the final stages of oocyte maturation were not captured. Additional research on the reproductive biology and ecology of this under-studied species is necessary to determine its role in tropical estuaries in the southern Gulf of Mexico. Information learned from areas in the center of its distribution may aid in conserving the species at the periphery of its range in Florida, where it is considered threatened.

RESUMEN La guavena, *Gobiomorus dormitor*, es una especie bentónica eurihalina y es muy abundante en las desembocaduras de los ríos, lagunas costeras y lugares fuera de la influencia marina, desde el sur de la Florida hasta la Guyana Holandesa. Hay pocos estudios de su ciclo de vida, ecología y abundancia, particularmente dentro de aguas mexicanas. Se realizaron 9 muestreos en el estuario de Tecolutla, Veracruz, México, entre octubre de 1995 y mayo de 1998, para estimar el desarrollo gonádico y el dimorfismo sexual de *G. dormitor*. Fueron capturados un total de 94 organismos de entre 15–260 mm de longitud patron y 0.05–181 gramos. Sesenta organismos fueron hembras y doce fueron machos; 22 peces fueron juveniles y no mostraron dimorfismo sexual externo. Ambos estadios, juvenil y adulto, de *G. dormitor* fueron capturados todo el año en camas de pastos y áreas adyacentes poco profundas, lodosas o arenosas. Este estudio ha mostrado que *G. dormitor* es residente y sufre maduración sexual en el estuario de Tecolutla. La evidencia histológica sugiere que machos y hembras sufren una recrudescencia gonádica en el estuario y tiene una estación reproductiva que se extiende desde mayo hasta finales de noviembre. Sin embargo, no está claro si esta especie desova actualmente en el estuario, desde que hembras en estadio final de maduración del ovocito no fueron capturadas. En investigaciones adicionales de la biología reproductiva y ecología de la especie en estudio, es necesario determinar su papel en estuarios tropicales del sureste del Golfo de México. La información obtenida de áreas en el centro de su distribución, puede ayudar en la conservación de la especie en la periferia de su intervalo en Florida, donde son considerados como peces amenazados.

INTRODUCTION

The eleotrid fishes (Family: Eleotridae) are one of the most widely distributed families world-wide and are commonly found in estuaries. In the Americas, the eleotrids are most abundant in Central America, with various species extending north to the United States and south to Brazil (Nordlie 1981). The bigmouth sleeper, *Gobiomorus dormitor* (Martinez and Sanabria 1993), occurs in the estuarine system of Tecolutla, Veracruz, and is known locally as "guavina." *Gobiomorus dormitor* is a benthic, euryhaline species, very abundant in river mouths, coastal lagoons,

and sites away from marine influence (Darnell 1955, Castro-Aguirre 1978) from south Florida to Dutch Guyana, and is associated with muddy bottom, mangrove habitat and seagrass beds in Larios and Silvenia estuaries in Tecolutla, Veracruz (Torres 1992). This species is considered threatened in Florida (Gilmore 1992, Woods 1994).

There are few studies on the life history, ecology, and abundance of *G. dormitor*, particularly within Mexican waters. Darnell (1955) reported that *G. dormitor* exhibits nocturnal terrestrial habitats in headwaters of the Rio Tamesi in Mexico and is an opportunistic forager. McKaye et al. (1979a) reported that cichlids, poecilids, and

atherinids were the preferred prey of *G. dormitor* in Lake Jiloá, Nicaragua. The species inhabits stony areas and migrates to deeper water during the dry season, when spawning occurs (McKaye et al. 1979a). In contrast to other elotrids, *G. dormitor* appears to prefer open habitats adjacent to vegetation in freshwater streams (Gilmore and Hastings 1983, Winemiller and Ponwith 1998). Torres (1992) studied the larval stages of the families Gobiidae and Eleotridae in 6 estuarine systems in Veracruz state and reported that *G. dormitor* was the most abundant species in the 6 systems. *Gobiomorus dormitor* larvae were less abundant in the dry season and more abundant during rainy seasons in those estuarine systems. Adults are known to move downstream during the rainy season in estuarine areas of Mexico (Darnell 1962) and Florida (Gilmore and Hastings 1983). *Gobiomorus dormitor* was the second most abundant species in the Laguna Tortuguero, Costa Rica (Nordlie 1981), although Winemiller and Ponswith (1998) found the species to be the 4th most abundant species in the freshwater tributaries of the same system. *Gobiomorus dormitor* has been shown to be a successful invasive species when introduced into a crater lake in Nicaragua, displaying exponential growth and higher foraging success than a natural population in a nearby lake (Bedarf et al. 2001).

There is little information on the reproduction of *G. dormitor*. The breeding area for *G. dormitor* in Nicaraguan crater lakes ranges between 12–15 m. Nests are 6–11 cm wide, 60–120 cm long, and 40–90 cm deep and are located in deep, narrow rock fissures (Mc Kaye 1977, McKaye et al. 1979b). Both parents defend the nesting area, and females spawn about 4,000–6,000 eggs in one day (McKaye et al 1979b). Winemiller and Ponwith (1998) and Bedarf et al. (2001) suggested year-round reproduction occurred in the Tortuguero, Costa Rica, estuarine system and in a crater lake in Nicaragua, based on gonadal observations and the occurrence of juveniles.

The reproductive life cycle of *G. dormitor* in Mexican waters is unknown. Thus, the present work contributes to the knowledge of some reproductive aspects of *G. dormitor*. The objectives of this study are 1) to determine the external morphological structures of sexual organs that permit differentiation between female and male *G. dormitor*, 2) to describe macro- and microscopically the gonadal morphology and sexual maturity classes of *G. dormitor*, and 3) to establish the reproductive season of *G. dormitor* in the Tecolutla estuary, Veracruz, Mexico.

Study area

The Tecolutla estuary is located at 20°30'N and 97°01'W in the Gutierrez Zamora municipality in Veracruz

TABLE 1

Temperature and salinity data recorded during collections of *Gobiomorous dormitor* in Tecolutla River during this study.

Month	Temperature (°C)	Salinity (psu)
October	22	0
November	19	0
December	17	0
January	14	2
February	16	4
March	19	6
April	23	3
May	25	12

state, Mexico. Tecolutla estuary is oriented in a southwest to northwest direction, and the Tecolutla River is the principal inflow of fresh water. The estuary is divided into 2 principal sections before entering the Gulf of Mexico, the Larios estuary, and the El Negro estuary which has a smaller estuary to the east, the Silvenia estuary. The estuary has a warm, humid climate characterized by summer rains and an oscillation of annual temperature no more than 7 °C. The emergent vegetation in the estuary is principally composed of red mangrove (*Rhizopora mangle*), black mangrove (*Avicennia germinans*), and white mangrove (*Laguncularia racemosa*), with considerable seagrass, *Ruppia maritima*.

MATERIAL AND METHODS

Field collections

Nine trips to Tecolutla estuary were taken between October 1995 and May 1998. Fishes were captured with a 50 m long beach seine constructed with 12.7 mm mesh net in *Ruppia maritima* seagrass beds. Fish were placed in 20 L buckets, sacrificed in ice water, and fixed in 10% formalin for transport to the laboratory. Water temperature and salinity was recorded at the time of sampling at each site.

Laboratory procedures

In the laboratory, fish were rinsed overnight in running water and identified (Alvarez 1970, Castro-Aguirre 1978). Meristic and morphometric measures were taken on the preserved fish with calipers, and all individuals were weighed to the nearest 0.01 g. The fish were dissected to extract the urogenital apparatus in both sexes, and the gonads were measured using vernier calipers and weighed to the nearest 0.01g on an analytical balance. A macroscopic description of the accessory glandule, gonad, urinary bladder, and genital papilla was made for both sexes.
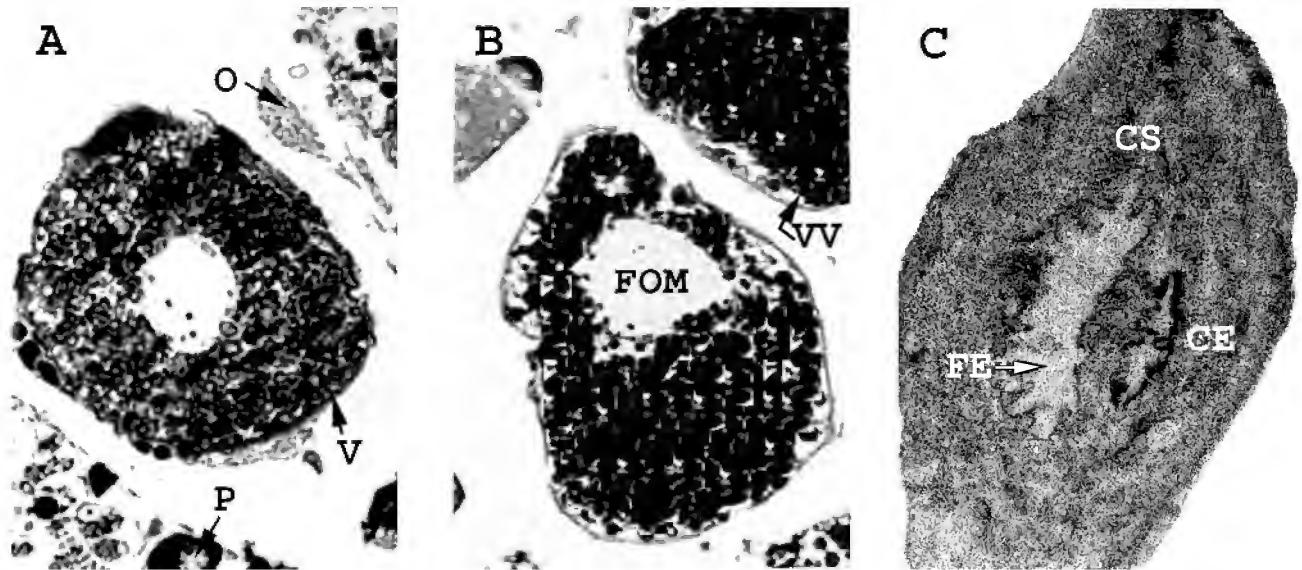
Figure 1. Histological sections of the urogenital aparatus of female *Gobiomorus dormitor*. A) The ovary of a mature fish showing a nest of oogonia (O), perinucleolar stage oocytes (P), and an oocyte in secondary vitellogenesis (V), 200X. B) An oocyte in the migratory nucleus stage (FOM). Note the presence of an oocyte in the vitellogenin vesicle stage (VV), 200X. C) Transverse section of female papilla. Note the major duct with flat epithelial cells (FE), minor duct with cubic epithelium (CE) and connective stroma (CS), 40 X.

For microscopic descriptions, the urogenital apparatus was processed following standard histological techniques. Tissues were embedded in paraffin and sectioned at 5 μm. For each organ different staining techniques were used: ovaries—hematoxylin-eosin (H-E), and Masson trichrome stains; testes—H-E, Masson trichrome and Hemotoxylin-Ferrous (H-F); seminal vesicle—H-F; urinary bladder and female papilla—H-E; male papilla—H-E and H-F. Oocyte stages were classified following Rodriguez (1992), while spermatogenic stages were classified following Hyder (1969). Oocyte diameter (μm) was measured with an ocular micrometer.

RESULTS

A total of 94 individuals ranging from 15–260 mm SL and 0.05–181 g, were captured during the course of this study. Seventy-two specimens were adults (60 females, 12 males) and 22 were juveniles that did not show external sexual dimorphism. Both juvenile and adult stages of *G. dormitor* were captured year-round in *R. maritima* grass-beds and adjacent shallow, muddy or sandy areas in Larios and Silvenia estuaries. Water temperature ranged between 14 and 25 °C and salinity between 0 and 12 psu (Table 1).

Female reproductive system

The female urogenital apparatus is composed of 1 pair of ovaries, urinary bladder, and genital papilla. The ovaries have a ribbon form and a cream color, with a smooth appearance in the immature and regressed classes. Oocytes become visible during vitellogenesis, and the ovary takes on a more lumpish appearance. There is a marked difference in size, with the right ovary smaller than the left. Both ovaries have a *tunica albuginea*, consisting of a thick layer of smooth muscle and dense, white connective tissue that forms septa in the interior of the ovary. In cross section, the ovarian lamella are visible and contain oocytes in different stages of maturation, indicating asynchronous oocyte development.

Eight stages of oocyte development were identified in *G. dormitor*. Oogonia were small cells, with an acidophilic cytoplasm and a strongly basophilic nucleus. They occurred in nests in the *tunica albuginea* between the lamellae (Figure 1a). The chromatin nucleolar oocytes ranged in size from 12–22 μm and were strongly basophilic with multiple nucleoli. Oocytes in the perinucleolar stage ranged in size from 23–79 μm, were strongly basophilic, and were characterized by a large nucleus, nucleoli distributed in the periphery, and the appearance of the follicle (Figure 1a). The vitellogenin vesicle stage (80–100 μm; Figure 1b) is characterized by an oval shape and the appearance of small, light purple vesicles in the cytoplasm. In the primary vitellogenesis stage (101–129 μm), the oocyte loses its oval shape and becomes square or triangular. Vitellogenin globules begin to appear in the cytoplasm, and the oocyte becomes eosinophilic. In secondary vitellogensis (130–163 μm, Figure 1a), the oocyte, nucleus, and nucleoli return to an oval shape. There is a
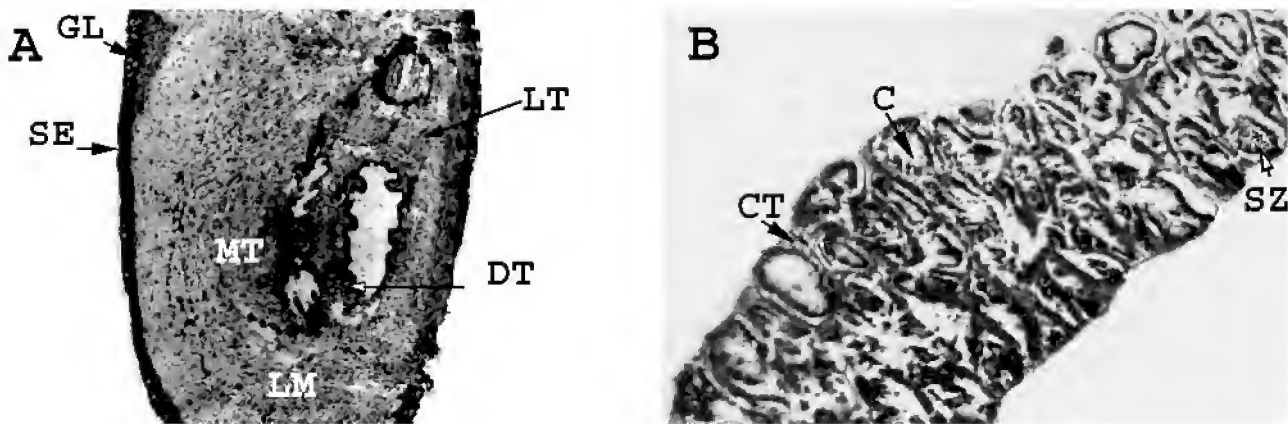
Figure 2. **Histological sections of accessory gonadal organs in male *Gobiomorus dormitor*. A) Transverse section of male genital papilla showing flat stratified epithelium (SE), layer of striated transverse muscle tissue (MT), striated longitudinal muscle tissue (LM), loose connective tissue (LT) and dense connective tissue (DT). Note the presence of small unicellular secretory glandules (GL), 40X. B) Seminal vesicle cyst (C) containing spermatozoa (SZ) and cyst wall formed of connective tissue (CT), 200 X.**

large accumulation of vitellogenin globules in the ooplasma, and the oocyte rapidly increases in size. In the migratory nucleus stage (240–380 μm, Figure 1b) the nucleus begins to migrate to the animal pole, the nucleoli are scarce, the globules of vitellogenin increase in size, and the *zona radiata* increases in thickness. Migratory nucleus oocytes are in the first stage of final oocyte maturation (FOM), indicating spawning is imminent.

The female urogenital papilla is an elongate structure with 2 central orifices, one below the other (Figure 1c). The lumen of the duct closer to the animal body has an irregular, contorted shape and a layer of flat epithelial cells. The second duct closer to the organism's skin is smaller, also of irregular shape and composed of cubic epithelium cells of glandular appearance. The glandular body is formed by conjunctive tissue with components of connective fibers, fibroblasts and blood vessels of different sizes. A stratified flat epithelium of 4 or 5 to 14 layers is present in the external portion.

Male reproductive system

The male urogenital apparatus of *G. dormitor* consists of 1 pair of testes, seminal vesicles, and genital papilla. The *G. dormitor* testis is the unrestricted spermatogonial type (sensu Grier 1981), with spermatogenesis occurring within spermatocysts along the length of the lobules. All stages of spermatogenesis were identified in the testis of *G. dormitor*, including spermatogonia, spermatocytes, spermatids, and tailed spermatozoa.

The male urogenital papilla has a fusiform or extended shape with 2 central orifices, one under the other. The bigger and extended opening has contortions or projections in the lumen formed of cubic epithelium with basophilic basal nuclei. Under this layer there is connec-

tive tissue. The second opening also has an irregular form. Surrounding the openings are different layers of tissue; dense connective tissue, loose connective tissue, striated longitudinal muscle, striated transverse muscle, and the flat stratified epithelium of the skin (Figure 2a). Small unicellular glandules with PAS-positive stain were found in the epithelium, indicating a secretory function.

The seminal vesicles of *G. dormitor* are soft structures with a white or cream color that connect with the testes by means of a light fold or crease. Both vesicles are small extensions from the testes or sperm duct and are formed from a relatively few number of cells or tubules. A layer of connective tissue and blood vessels was observed histologically with H-E staining. The seminal vesicle consists of chambers, with glandular epithelial cells in the periphery. Histochemical staining suggests a secretory function. Spermatozoa were observed in the majority of the seminal vesicles analyzed (Figure 2b), suggesting the seminal vesicle is a spermatozoa reservoir.

Reproductive seasonality

Females in the final stages of ovarian maturation were captured in May, September, and November from Tecolutla estuary, and females with vitellogenic oocytes in the ovary were found from April through November. However, females with vitellogenic oocytes were much more commonly taken from July through November (30–55% of females captured) than from April through June. This finding, in conjunction with the observation that the majority of males with spermatozoa in the sperm duct were captured from July through November, suggests the main reproductive season for this species in Tecolutla estuary is July through November.

DISCUSSION

In the Tecolutla, Veracruz estuary, juvenile and adult stages of *G. dormitor* were captured in seagrass beds and adjacent shallow, muddy, and sandy areas. Our findings are in agreement with those reported by Darnell (1962) who captured *G. dormitor* in shallow water with modest currents, Nordlie (1981) who found the species in a shallow, vegetated lower estuary in Costa Rica, and Gilmore and Hastings (1983) who collected adults in silt/sand bottoms near vegetation in freshwater creeks in Florida. In contrast, juvenile *G. dormitor* were rarely captured in vegetation in freshwater streams in Costa Rica (Winemiller and Ponwith 1998), and both adults and juveniles were taken only in channel areas. Sexually mature individuals were taken year-round in Tecolutla, although large individuals have been previously suggested to be transitory (Nordlie 1981 and references therein) or absent (Gilmore and Hastings 1983) in estuaries.

In Tecolutla estuary, females with oocytes in the migratory nucleus stage were founded in May, September, and November, suggesting an extended spawning season. However, the percentages of vitellogenic females captured as well as males with spermatozoa in the sperm ducts suggest the major reproductive season in Tecolutla estuary is July through November. This is a later spawning season than previously reported. Nordlie (1981) reported mature *G. dormitor* were captured in May in Costa Rica, and McKaye (1977) found most breeding pairs of *G. dormitor* during May in Nicaraguan lakes, although observations were taken from February–September. However, competition for breeding sites with cichlids may have influenced the timing of the reproductive period in the Nicaraguan lakes (McKaye 1977). There is evidence that *G. dormitor* spawn year-round in Costa Rica and Nicaragua (Winemiller and Ponwith 1998; Bedarf et al. 2001), supporting evidence of the extended spawning season found in the Tecolutla estuary. The asynchronous oocyte development we observed suggests this species can spawn multiple times during the extended reproductive season, which coincides with reports by Nordlie (1981) and McKaye et al. (1979b). The final stages of FOM were not found in this study, perhaps because the female migrates to the coast to spawn (Darnell 1955, 1962), since spawning requires a hard substrate (McKay et al. 1979b) not present in Tecolutla estuary. However, the low sample size may have limited finding females in all stages of FOM.

The unique characteristic external morphology used to distinguish male from female *G. dormitor* is the presence of the genital papilla, which is observed in a few groups of fish such as the gobiids and eleotrids (Tavolga 1954; Miller 1986; Birdsong and Robins 1995). The function of the genital papilla is still disputed. The presence of small unicellular secretory glandules in the apical part of the papilla was observed in male *G. dormitor*. These glandules may secrete a mucoid substance, which could have a lubricant or seminal function, to help in transport of spermatozoa to the exterior. Bianco et al. (1987), who observed that the genital papilla of male *Economidichthys pygmaeus* (Gobiidae) also had a secretory function, suggested it may be important in nest building or in adhesion to the substrate to keep newly spawned eggs from being displaced by currents. Hoffman (1963) mentioned that in male *Opsanus tau*, the apical portion of the papilla had blood vessels of different sizes, forming a vascular net with probable erectile function. The function of the female papilla is even less clear. The papilla of *G. dormitor* may have a contractile function, while the network of blood vessels forms a spongy structure which could aid in ovoposition. However, secretory glandules similar to those found in the male papilla were not seen in the female. Weisel (1949) reported the presence of the female urogenital papilla in *Gillichthys* and said that the function of the papilla could be in relation to the sexual cycle, an idea also mentioned by Hoffman (1963) who described this structure in *O. tau*.

The seminal vesicles are accessory sexual organs found in several families of teleost fish, such as Blennidae and Gobiidae. The seminal vesicle of *G. dormitor* is type A, as described by Fishelson (1991). The presence of secretory glandular cells in the seminal vesicle together with spermatozoa suggests the structure has storage and nutritive functions for the spermatozoa, as described by De Jonge et al. (1989), Lahnsteiner et al. (1990), Seiwald and Patzner (1989) and Patzner (1991).

This study has shown that *G. dormitor* are resident and undergo sexual maturation in the Tecolutla estuary. Histological evidence suggests both males and females undergo gonadal recrudescence in the estuary and have an extended reproductive season from May through November. However, it is unclear if the species actually spawns in the estuary, since females in the final stages of FOM were not captured. Additional research on the reproductive biology and ecology of this under-studied species is necessary to determine its role in tropical estuaries in the southern Gulf of Mexico. Information learned from areas in the center of its distribution may aid in conserving the species at the periphery of its range in Florida, where it is considered threatened (Gilmore 1992, Music et al. 2001).

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Reproductive Biology of the Opossum Pipefish, *Microphis brachyurus lineatus*, in Tecolutla Estuary, Veracruz, Mexico

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REPRODUCTIVE BIOLOGY OF THE OPOSSUM PIPEFISH, *MICROPHIS BRACHYURUS LINEATUS*, IN TECOLUTLA ESTUARY, VERACRUZ, MEXICO

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ABSTRACT The reproductive biology of the opossum pipefish, *Microphis brachyurus lineatus*, was investigated in Tecolutla estuary, Veracruz, Mexico, to determine sex ratio, size at maturity, gonadal and brood pouch histology, reproductive seasonality, and fecundity of this little-known syngnathid. A total of 345 fish were collected between 1995–1998, with an overall sex ratio of 1:1.35 favoring females. Brooding males made up 45% of the population, resulting in an operational sex ratio of 1:2.45 heavily favoring females. All males > 90 mm SL were considered sexually mature, as this was the size at which the brood pouch was clearly developed. Females > 110 mm SL were sexually mature, and had asynchronous oocyte development. Opossum pipefish appear to have a year-round reproductive season in Tecolutla estuary, as females with vitellogenic oocytes and males with eggs in the brood pouch were captured during every month of the year. The number of eggs in the brood pouch was positively correlated with male SL (*P* < 0.001), and in all but 2 cases males brooded embryos from a single female. The brood pouch is not enclosed by a membrane, and each egg is embedded in a septum consisting of epithelial tissue and numerous blood vessels. Evidence from this study suggests *M. brachyurus lineatus* may be a sequentially polygamous species with sex-role reversal reproductive behavior, although additional research is necessary to confirm the reproductive ecology and behavior of the species.

RESUMEN Fue investigada la biología reproductiva del pez pipa *Microphis brachyurus lineatus*, en el estuario de Tecolutla, Veracruz, México, para determinar la proporción sexual, el tamaño de maduración, la histología gonádica y de la bolsa incubadora, la estacionalidad reproductiva y la fecundidad de este signátido poco conocido. Fueron colectados un total de 345 peces, entre 1995 y 1998, con una proporción sexual de 1:1.35 a favor de las hembras. Los machos incubadores comprenden el 45% de la población, con el resultado de una proporción sexual operacional de 1:2.45 a favor de las hembras. Todos los machos mayores a 90 mm de longitud patron fueron considerados sexualmente maduros, ya que este fue el tamaño al cual la bolsa incubadora estuvo claramente desarrollada. Las hembras mayores a 110 mm de longitud patron estuvieron sexualmente maduras y tuvieron un desarrollo asincrónico de los ovocitos. El pez pipa parece tener una estación reproductiva durante todo el año en el estuario de Tecolutla, ya que las hembras con ovocitos vitelogénicos y los machos con huevos en el saco incubador fueron capturados durante todos los meses del año. El número de huevos en la bolsa incubadora estuvo positivamente correlacionado con la longitud patron del macho (*P* < 0.001) y en todos, menos en 2 casos, los embriones de la bolsa incubadora del macho fueron de una sola hembra. La bolsa incubadora no está encerrada por una membrana, y cada huevo está depositado en un septo, que consiste de tejido epitelial y numerosos vasos sanguíneos. La evidencia de este estudio sugiere que *M. brachyurus lineatus* puede ser una especie secuencialmente polígama, con una conducta reproductiva de reversión sexual, aunque es necesario estudios adicionalales para confirmar la ecología reproductiva y comportamiento de la especie.

INTRODUCTION

Various species of fish have developed a brood protection strategy to elevate the probability of survival and reproductive success. One family widely known for parental care is the Syngnathidae (seahorses and pipefishes), in which the males exclusively brood and care for the young. There has been much recent interest in the reproductive ecology of the syngnathids in an effort to more fully understand the evolution of sexual differences and the mating system. Within the syngnathids, there are about 300 species of pipefish divided into 35 genera (Nelson

1994). Species differ in the external morphology of the brood pouch, which varies from a series of lateral dermal plates to a pouch that is completely closed. In some species, no pouch is present, and the eggs are adhered to the ventral side of the male (Dawson 1982). The reproductive behavior of syngnathids exhibits similar variation, ranging from monogamy, typical of seahorses (Jones et al. 1998) and some pipefishes (Berglund et al. 1989, Vincent et al. 1995), to polygamy, as seen in a variety of pipefishes (Berglund et al. 1988, 1989, Berglund and Rosenqvist 1990, Vincent et al. 1995, Jones and Avise 1997, Jones et al. 2000, 2001). Finally, there appears to be some correla-

tion between monogamy and "conventional" sex roles (males competing for female mates) versus polygamy and "sex-role reversal" (females choosing male mates), in the syngnathids studied (Vincent et al. 1992). Furthermore, sex-role reversal often seems to be related to a female-biased operational sex ratio (OSR; Vincent et al. 1992, Kvarnemo and Ahnesjo 1996).

Overall, paternal care, development, gonadal histology, importance of the brood pouch, and mating systems have been well documented for common syngnathid species in the western North Atlantic such as *Sygnathus typhle* (Berglund et al. 1988, Berglund 1991, Ahnesjö 1992, Vincent et al. 1994, Jones et al. 2000), *S. fuscus* (Anderson 1968, Hareseign and Shumway 1980, Roelke and Sogard 1993, Campbell and Able 1998), *S. scovelli* (Quast and Howe 1980, Begovac and Wallace 1987, 1988, Azzarello 1991, Jones and Avise 1997) and *Hippocampus erectus* (Linton and Soloff 1964, Selman et al. 1991). However, there is little available information on the opossum pipefish, *Microphis brachyurus lineatus*. This species ranges from south of New Jersey, USA, to Sao Paulo, Brazil, including the Gulf of Mexico (GOM), Cuba, and the Antilles, and has been found in the west Pacific Ocean only off Panama (Dawson 1982). The opossum pipefish is considered threatened in Florida and Texas and was designated as a candidate species on the federal threatened and endangered species list in 1999 (Federal Register 1999, Music et al. 2001). Permanent populations are limited to tropical and subtropical areas, and breeding adults typically occur in shallow, freshwater areas with emergent vegetation (Gilmore and Gilbert 1992), although larvae and juveniles are found in higher salinity areas (Gilmore 1977). There is little reproductive information available on the species, and nothing is known regarding its reproductive ecology. In Jucú River, Brazil, summer and winter reproductive periods have been found (Perrone 1989), while reproduction typically occurs in the GOM and Caribbean Sea from May through November during the rainy season (Frias-Torres 2002). Therefore, the objectives of the present study are to better describe certain aspects of the reproduction of *M. brachyurus lineatus* in Mexico. Specifically, we determine the sexual proportion of the species, size for external differentiation between females and males, the number of eggs in the brood pouch, and provide macroscopic and histological descriptions of the ovary, testis, and brood pouch.

MATERIALS AND METHODS

Periodic sampling was performed between 1995 and 1998 and covered an annual cycle in Tecolutla estuary, Veracruz, Mexico (20°30'N, 97°01'W). Specimens were captured during daylight hours in shallow (1.5 m) grass-beds along the bank of Larios estuary using a beach seine (2.5 m x 1.20 m, mesh size 500 µm). The samples were placed in bags and preserved in 10% buffered formalin prior to transportation to the laboratory. Species identification was verified with Castro-Aguirre (1978) and Dawson (1982). All specimens were washed in running water, and measured for standard length (SL, mm) and wet weight (ww, 0.0001 g). The presence or absence of a brood pouch was noted; this information was used to determine both sexual proportions as well as the size at sexual maturity for males following Gilmore and Gilbert (1992). To determine fecundity, the number of eggs in the brood pouch were counted using dissection needles and a stereo microscope. Additionally, mature oocytes from the ovaries of 13 females were counted in the same manner.

Gonads of males and females were removed, measured, weighed, and processed for histological analysis following standard techniques, with the substitution of amyl alcohol for clearing the tissues. Tissues were embedded in paraffin and sectioned at 5 µm. Ovarian tissue from 11 females (93–184 mm TL) was stained with hematoxylin-eosin (H-E) and Masson trichrome to classify ovarian development following Brown-Peterson (2003). Testes from 16 males (93–174 mm TL, of which 37.5% were egg carriers) were stained with H-E, ferric hematoxylin and Masson trichrome and classified for testicular and spermatogenic development following Hyder (1969) and Grier (1981). One160 mm TL male, with eggs in the brood pouch, was treated with disodium EDTA for 15 d to soften the bony plaques prior to standard histological processing. Sections were cut from 2 different levels, distal and proximal to the anus, and stained using H-E and Masson trichrome.

Differences between males and females in SL, ww, and size at sexual maturity were evaluated using the Student t-test. Linear regression was used to determine the relationship between the number of eggs in the brood pouch as the dependent variable and male SL as the independent variable. In all cases, differences were considered significant if $P \leq 0.05$.

RESULTS

Sexual proportion, length-weight relationship, and fecundity

A total of 345 *Microphis brachyurus lineatus*, ranging in size from 64–205 mm SL and 0.0910–4.8203 g, were collected. The minimum size in which the brood pouch was clearly developed was 90 mm SL; thus, all fish <90
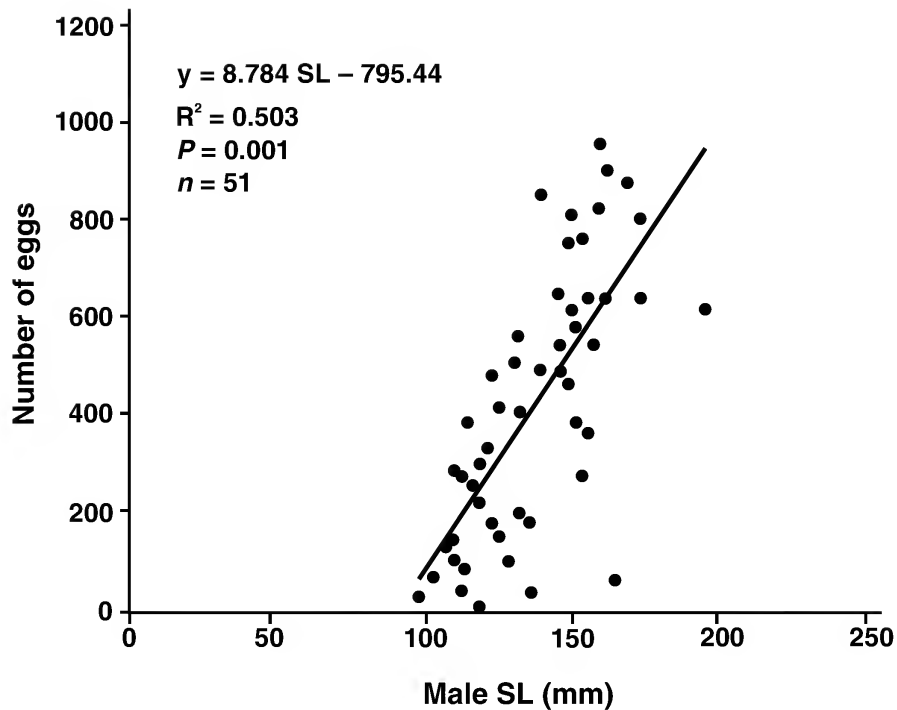
Figure 1. Linear regression of the number of eggs in the brood pouch vs. SL of male *Microphis brachyurus lineatus*.

mm SL were considered juveniles. Overall, 159 females (46%; 90–205 mm SL), 118 males (34%; 90–200 mm SL) and 68 juveniles (20%, 65–90 mm SL) were captured. Only 45% of males ranging in size from 99–196 mm SL had eggs in the brood pouch. Overall, the sex ratio was 1:1.35 favoring females. However, the ratio of reproductively available males (those with no eggs in the brood pouch) to females was 1:2.45, resulting in an OSR of 29%, heavily favoring females.

There was a significant difference in both SL ($t = -31.40$; $P < 0.001$, $n = 259$) and ww ($t = -15.76$; $P < 0.001$,

$n = 259$) between males and females when all sizes were combined. Among sexually mature males and females, there was also a significant difference in SL ($t = -21.31$; $P < 0.001$, $n = 189$) and ww ($t = -14.77$; $P < 0.001$, $n = 189$), with males heavier at a given length.

The number of eggs in the brood pouch ranged from 10–953, with a mean of 409 eggs. In contrast, the mean number of mature oocytes in the ovary was 765. The fertilized egg is oval, with a diameter along the long axis of 0.8-1.1 mm. Each egg in the pouch was surrounded by spongy tissue (see descriptions below). There was a significant,
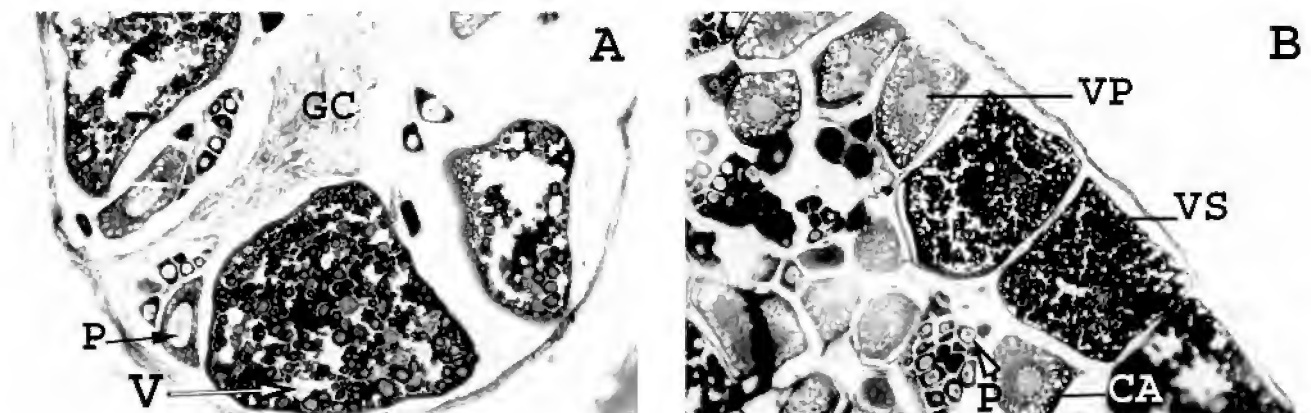
Figure 2. Histological sections from the ovary of *M. brachyurus lineatus*. A) Transverse section of the ovary, showing the U-shaped projection from the germinal cord. Germinal cord (GC), perinucleolar oocyte (P), vitellogenic oocyte (V), 100X. B) Longitudinal section of the ovary showing asynchronous oocyte development. Perinucleolar oocyte (P), cortical alveolar oocyte (CA), primary vitellogenic oocyte (VP), secondary vitellogenic oocyte (VS), 400X.

TABLE 1

Oocyte stages found in ovaries of *Microphis brachyurus lineatus* from Tecolutla estuary, Veracruz, Mexico.

Oocyte Stage	Diameter (μm)	Characteristics
Oogonia	2.6	Spherical; 1–3 nucleoli
Chromatin nucleolar	6–29	Large nucleus; 3–16 nucleoli
Perinucleolar	29–80	Basophilic; 9–29 nucleoli around nucleus
Cortical alveolar	80–150	Chorion visible; small lipid droplets; 9–20 nucleoli
Vitellogenic (Primary, Secondary, Tertiary)	150–480	Well defined chorion; vitellogenin spheres central (primary), throughout (secondary), or fused (tertiary); nucleoli peripheral (primary, secondary) or throughout nucleus (tertiary)
Mature	800	Trapezoid shape

positive relationship between male SL and egg number ($R^2 = 0.503$, $P < 0.001$, $n = 51$; Figure 1). In organisms with the brood pouch only partially full of eggs, the anterior portion of the pouch was always empty, suggesting oviposition occurs first in the posterior portion of the pouch.

Macroscopic and microscopic description of the ovary

The ovaries are paired structures that are fused in the terminal part of the body and occupy 3/4 of the trunk length of the female. The ovaries of a mature female (mean = 158 mm SL) measured 35 mm, weighed 0.200 g and were longitudinally asymmetrical. In 57% of the females studied, the right ovary was slightly longer than the left (0.3–2.8 mm difference).

Histologically, the germinal cord of *M. brachyurus lineatus* runs along the medial dorsal part of the ovary and is formed by connective tissue and germinal cells that later develop into oocytes. The previtellogenic oocytes form on each side of the germinal cord in a U-shaped projection directed toward the lumen of the ovary (Figure 2a). Oocyte development occurs sequentially across the cord and is termed the maturity line. The maturity line is defined by the position of vitellogenic oocytes which are ready for maturation and ovulation.

Microphis brachyurus lineatus show asynchronous oocyte development (Figure 2b). We identified 6 oocyte stages in the specimens we examined (Table 1). Oogonia, chromatin nucleolar, and perinucleolar oocytes were found in the ovaries of all females, regardless of reproductive season or SL. Ovarian recrudescence begins with the appearance of cortical alveolar oocytes. All 3 stages of vitellogenic oocytes were commonly seen, although final oocyte maturation was not observed in any samples. No females < 110 mm SL were observed with oocytes in the cortical alveolar, vitellogenic, or mature stages, suggesting sexual maturity is not reached until this size.

Macroscopic and microscopic description of the testis

The testes are paired structures in a ventral position and can be divided into 2 regions. The first is distal to the anus, occupies 3/4 of the gonad, is extremely thin, and has a cylindrical shape. The second part is a clearly expanded region proximal to the anus, consisting of the remaining 4th of the testis. The testis can occupy more than 3 quarters of the trunk. An adult male (mean = 140 mm SL) had testes of 25 mm and 0.0035 g. The length of the right testis was slightly greater in 63% of the organisms studied.

Histologically, the testes of the oppossum pipefish are the lobular, restricted spermatogonial type. Spermatogonia were found only at the distal, "blind" end of the testis, and spermatocysts were not obvious in that section. Each primary spermatogonium was surrounded by connective tissue. In the proximal portion of the testis, spermatocysts were easily observed. Spermatozoa were found both in cysts and in the lumen of the lobule. The diameter of the spermatozoa was about 8.3 μm; the nucleus (4.48 μm) was often off-center in spermatozoa in the lumen of the lobule, but the nucleolus (1.6 μm) remained centric. There was no evidence of flagella on the spermatozoa, although a small, pointed protrusion was often visible on one side of the cell.

Reproductive season

Opossum pipefish in the Tecolutla estuary appear to have a year-round reproductive season. Females with vitellogenic oocytes were collected during every sampling event, which covered all 12 months of the year. Additionally, we captured males with recently spawned eggs, eggs in advanced phases of development, and embryos almost ready to hatch during each sampling event. However, within the same organism, all eggs present were in the same development stage, with the exception of 2 males containing eggs in different phases of development.
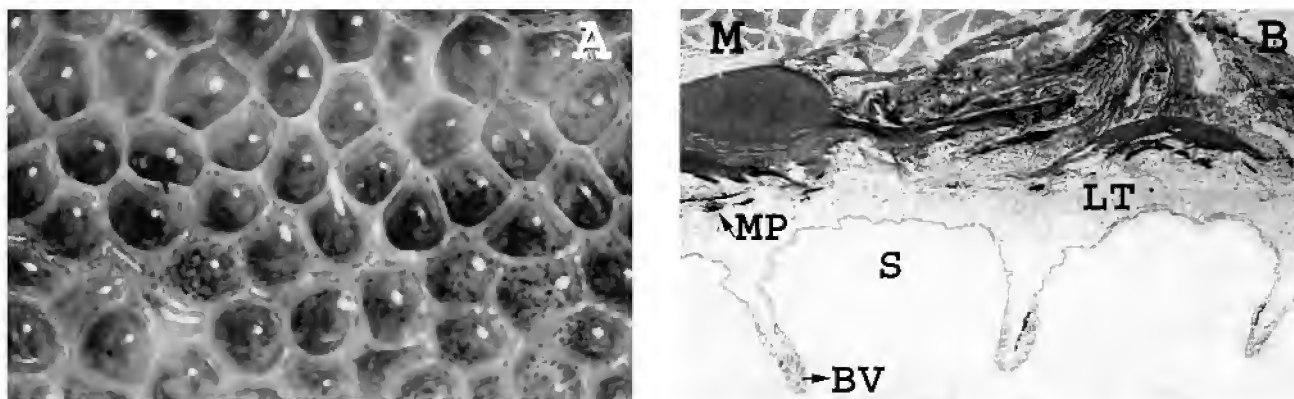
Figure 3. The brood pouch of male *M. brachyurus lineatus*. A) Internal tissue of the brood pouch, containing developing embryos in individual cells in a honeycomb-like arrangement, 15X. B) Transverse histological section, showing the internal septum (S) where each egg lodges, muscle (M), melanophores (MP), loose connective tissue (LT), and blood vessels (BV), 100 X.

Macroscopic and microscopic description of the brood pouch

The brood pouch begins at the first trunk ring, ends just anterior of the first anal ring, and is not enclosed by a membrane. In the interior of the pouch, the eggs are embedded in a honeycomb-like spongy tissue of hexagonal cells in 3 to 12 (generally 10) transverse rows in males 145–174 mm SL (Figure 3a). In transverse histological sections, the elongated extensions that form the septum of each internal cell in the brood pouch are distinct. The basal zone of the chamber where the eggs are deposited is delineated by an external layer of flat epithelial tissue that rests on a thick layer of loose connective tissue containing small blood vessels dispersed throughout (Figure 3b). The flat epithelial tissue of the elongations in the chamber is stratified, principally in the apical part where there are 4 layers of tissue. A large number of blood vessels of different diameters are present in each epithelial layer. Melanophores are present in the marginal portion of the epidermis and in the muscle of the body (Figure 3b).

DISCUSSION

Syngnathids are considered to be a true estuarine species, spending their entire life cycle in the estuary. We found opossum pipefish > 64 mm SL in every sample within the Tecolutla estuary but did not capture young juveniles. This is similar to findings by Gilmore (1977), who found no opossum pipefish < 60 mm SL in the Indian River Lagoon, Florida. The lack of young juveniles in the low salinity estuary of Tecolutla supports hypotheses that larvae migrate offshore to develop (Gilmore 1977, Frias-Torres 2002). It has been proposed that juveniles are transported back to tropical estuarine areas by the Caribbean, Loop and Antilles Currents (Frias-Torres 2002).

The presence of eggs in the brood pouch throughout the year indicates *M. brachyurus lineatus* does not have a specific reproductive season, confirming descriptions by Perrone (1989) for the same species in Brazil. Histological inspection of the ovaries found asynchronous oocyte development. Furthermore, females with vitellogenic oocytes were present throughout the year. In Indian River Lagoon, Florida, males with eggs in the brood pouch were reported during the wet season, May through November (Gilmore 1977). Brooding males were found only from July through September in Mississippi (Dawson 1970). Perhaps in truly tropical areas, such as Tecolutla estuary, at the Tropic of Cancer, and Espirito Santo, Brazil at the Tropic of Capricorn, the reproductive season is year-round, whereas it is shortened in warm-temperate and subtropical waters. Since egg maturation is dependent upon food availability in pipefishes (J. Wetzel, pers. comm., Presbyterian College, Clinton, SC), the shortened reproductive season in non-tropical regions may be a function of reduced food availability during the cooler dry season.

Male opossum pipefish from Tecolutla estuary appear to reach sexual maturity at a smaller size than previously reported for the species. The brood pouch could be distinguished in males as small as 90 mm SL in Tecolutla, and males as small as 99 mm SL carried eggs. This is similar to findings from Jucú River, Brazil, where the smallest male with a developed brood pouch was 95 mm SL, although the size at 50% sexual maturity was calculated to be 112 mm SL (Perrone 1990). In contrast, the smallest males with developed brood pouches were 105 mm SL (Loxahatchee, Florida and Biloxi, Mississippi), 106 mm SL (Mexico and Panama), to 110 mm SL (Sebastian River, Florida) (Frias-Torres 2002). This discrepancy in size at sexual maturity could be due to differences in sampling among areas.

The lobular, restricted spermatogonial testicular structure of opossum pipefish is commonly found in atherinomorph species (Grier 1981) and is recognized by the presence of spermatogonia at the distal end of the testis. The size of the spermatozoa in the terminal region of the testis is quite large, and is similar to the primitive spermatozoid described by Grier (1981) for species with external fertilization. In most teleosts, the germ cells become smaller as spermatogenesis progresses (Hyder 1969, Nagahama 1983). However, in *M. brachyurus lineatus*, the spermatozoa are larger than the spermatogonia. Furthermore, the spermatozoan of opossum pipefish is unique in that it does not have a flagellum, quite uncommon among teleosts (Mattei 1970). However, since the spermatozoa of the pipefish are expelled directly into the brood pouch to fertilize the eggs (Prein 1995), the requirement for mobility is reduced. Most likely, the spermatozoa move in an amoeboid fashion to fertilize the eggs, as has been shown in *Gymnarchus niloticus* (Mattei 1970), a species that also has spermatozoa without flagella.

Despite the existence of several studies on the brood pouch in syngnathids (Linton and Soloff 1964, Quast and Howe 1980, Haresign and Shumway 1980), this is the first study to evaluate an "open" brood pouch that does not have a membrane to isolate the eggs from the external environment. In *H. erectus* and *S. scovelli*, the spongy material in the brood pouch is permeable and permits gas interchange (Wetzel and Wourms 1991) and metabolic interchange of ions such as Ca^{+2} and Na^+, with their corresponding effect on osmoregulation (Linton and Soloff 1964, Quast and Howe 1980, Haresign and Shumway 1980). Possibly, the brood pouch of *M. brachyurus lineatus* does not participate in osmoregulation and its function is only to restrict gas exchange, as suggested by Azzarello (1991). Further studies to help in the understanding of active transport within the brood pouch tissue of *M. brachyurus lineatus* are necessary, as histological analysis is insufficient to establish whether the male supplies the embryos with energetic requirements through metabolic exchange during their development.

The reproductive ecology and mating strategies of the opossum pipefish can be examined from our data. In general, male opossum pipefish appear to mate with only one female at a time, since all eggs in the brood pouch of 96% of brooding males were in the same stage of development, suggesting contribution from just one female. However, this does not imply that the species is monogomous. Opossum pipefish could practice sequential polygamy, as in *Nerophis ophidion*, where the female gives one entire clutch to a male (Vincent et al. 1992). Female *M. brachyurus lineatus* deposit their eggs in the posterior portion of the brood pouch first, as is also the case with *S. typhle* (Berglund and Rosenqvist 1990), a species in which polygamy and multiple matings by the male are common (Berglund et al. 1988, Jones et al. 2000). We found some evidence of multiple matings by male *M. brachyrus lineatus*, as 2 males had 2 distinct batches of eggs in their brood pouches. It is possible that these males had first mated with smaller females, as male *S. typhle* that mate with small females are significantly more likely to mate with more than one female (Jones et al. 2000). Thus, the only way to definitively ascertain if *M. brachuyrus lineatus* is polygamous or monogomous is through microsatellite DNA markers to verify maternity of the embryos carried by males (Jones and Avise 1997).

The positive relationship between the number of eggs in the brood pouch and male size has been reported previously for opossum pipefish (Frias-Torres 2002) and is similar to reports for *S. typhle* (Berglund et al. 1986) but in contrast to *Nerophis ophidon* (Rosenqvist 1990), both polygamous pipefish (Vincent et al. 1992). Since *M. brachyurus lineatus* males appear to mate with only one female at a time, perhaps small females spawn their eggs in brood pouches of small males, whereas the larger females prefer the larger males. Thus, the number of eggs are "matched" to the energetic resources of the male, as suggested by Berglund et al. (1986). There is evidence that clutch size is positively correlated with the length of the female pipefish (Berglund et al. 1986, Ahnesjo 1992), suggesting clutch size can be used to determine if a male mated with a large or small female.

An understanding of the sexual roles in *M. brachyurus lineatus* is more difficult to determine from the available data. Pipefish with "conventional" sex roles, such as *S. scovelli* and *Syngnathoides biaculeatu*, tend to be monogomous (Jones and Avise 1997, Takahashi et al. 2003). However, pipefish with a strongly female-biased OSR, as seen here for opossum pipefish, are often polygamous (Vincent et al. 1992). Furthermore, a female-biased population, as seen in both Tecolutla estuary and in Jucú River, Brazil (Perrone 1989, 1990), may result in female competition for available males, a classic sex-role reversal pattern. However, while sex-role reversed pipefish tend to show sexual dimorphism, as in *N. ophidion* and *S. typhle* (Vincent et al. 1992), sexual dimorphism was not clearly demonstrated in *M. brachyurus lineatus*. Overall, evidence from this study suggests that opossum pipefish may be a sequentially polygamous species with sex-role reversal behavior. Clearly, additional research on the sex roles and breeding behavior of *M. brachyurus lineatus* is necessary for a complete understanding of their mating system, as the available data can be interpreted in a contradictory fashion.

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Gulf and Caribbean Research

Reproductive Structures and Early Life History of the Gulf Toadfish, *Opsanus beta*, in the Tecolutla Estuary, Veracruz, Mexico

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REPRODUCTIVE STRUCTURES AND EARLY LIFE HISTORY OF THE GULF TOADFISH, *OPSANUS BETA*, IN THE TECOLUTLA ESTUARY, VERACRUZ, MEXICO

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ABSTRACT Although the Gulf toadfish, *Opsanus beta*, is an abundant member of the nearshore Gulf of Mexico ichthyofaunal assemblage, little information exists regarding the ecology of the species, especially for southern Gulf of Mexico populations. We added to the existing knowledge of this species by describing the reproductive structures and examining the early life history of this species in the Tecolutla estuary, Mexico. Macro- and microscopic examination of 7 males showed spermatogenesis to be similar to other teleost species except for the occurrence of biflagellate spermatozoa. Histological examination of the male accessory gland showed 3 tissue layers, but their functions are still undetermined. We found asynchronous development of oocytes in the ovaries of 16 females, which may indicate multiple spawning over the long spawning season noted in this study. Batch fecundity estimates among females ranged from 79 to 518 mature ova with a mean ovum diameter of 3.5 mm. The above-mentioned factors along with large size at hatching, attached larval forms, and paternal care may account, in part, for the abundance of this species in highly dynamic systems.

RESUMEN Aunque el pez sapo del Golfo, *Opsanus beta,* es un miembro abundante del ensamble ictiofaunístico de las costas del Golfo de México, existe poca información acerca de la ecología de la especie, especialmente para las poblaciones del sureste del Golfo de México. Nosotros contribuimos al conocimiento existente de esta especie, describiendo las estructuras reproductoras y examinando las etapas tempranas del ciclo de vida de esta especie en el estuario de Tecolutla, México. El examen macro y microscópico de 7 individuos machos mostraron espermatogénesis similar al de otras especies de teleósteos, excepto por la presencia de espermatozoides biflagelados. El examen histológico de las glándulas accesorias del macho mostró una composición de tres capas de tejido, pero su función es aun indeterminada. Encontramos desarrollo asincrónico de los ovocitos de 16 hembras examinadas, que pueden indicar desoves múltiples a lo largo de la temporada de desove. La estimación de la fecundidad en las hembras examinadas presentó un intervalo de 79 a 518 huevos maduros con un diámetro de 3.5 mm. Los factores anteriores, junto con la talla grande al eclosionar, las formas larvales adheridas y el cuidado paterno, pueden responder a la abundancia de esta especie en sistemas muy dinámicos.

INTRODUCTION

The Batrachoididae is comprised of 69 species and 3 subfamilies, with the subfamily Batrachoidinae being most diverse in the western hemisphere (Nelson 1994). However, few directed biological studies exist regarding members of this family. Schultz and Reid (1937) described the taxonomic characters of *Opsanus* and gave a key for the Atlantic species, but this genus has received little attention in the ecological literature. Several studies have described the biology and ecology of the oyster toadfish, *O. tau.* For example, Gray and Winn (1961) studied its reproductive ecology and found sound production was related to reproductive season. Hoffman (1963a, 1963b) described the male gonads and seminal vesicles, including their respective ducts, noting seasonal variations in size and morphology. However, this information may not be applicable to congeneric species with a more tropical or subtropical distribution, such as the Gulf toadfish, *O. beta.* Most *O. beta* ecological studies to date have focused on

aspects of reproduction (Breder 1941), sound production (Walsh et al. 1987, 1989, Thorson and Fine 2002), or physiology (Walsh et al. 1990, Hopkins et al. 1997). *Opsanus beta* is a benthic species that commonly inhabits cavities, submerged tree trunks, rock crevices, or other objects. Although this species is highly abundant in subtropical seagrass environments (Serafy et al. 1997, Matheson et al. 1999), its use of 3-dimensional structured habitats hinders organism collection with conventional gears (Kuhlman 1998, Shervette et al. 2001).

The objectives of this study were to describe macro- and microscopic aspects of the gonads and provide information on early embryonic and larval development of *O. beta*, an abundant species in the Tecolutla, Veracruz estuarine system.

MATERIALS AND METHODS

Field Procedures

Five collections were made in the Tecolutla estuary (20°30'N, 97°01'W) during March, September, and

November of 1996, and March and April of 1997. Fish were collected with a 50 m seine (12.7 mm mesh). In the field, all fish were sacrificed, measured for standard length (SL, to 1 mm), and weighed wet (WW, to 0.1 g). Individuals were fixed in 10% formalin and placed in plastic bags for transport to the laboratory where species identification was verified (Castro-Aguirre 1978). We also searched for submerged objects containing *O. beta* eggs specifically during collecting trips in April 1996, May 1997, and June 1997. All objects found with eggs were placed in dish pans and transported to a field laboratory where the eggs were aerated and kept alive for 8 d. Additional observations of *O. beta* nests and gravid females were made during April, October, and November 1998.

Laboratory procedures

The gonads were extracted and weighed (g, 0.001) on an analytical balance. The gonads were post-fixed in 10% formalin, rinsed in water for 1 h, and processed with standard histological techniques using amyl alcohol to clear the tissues. Tissues were sectioned at 5 and 8 μm, stained with hematoxylin-eosin, ferric hematoxylin, aldehyde-fuchsin, or the PAS reaction, then examined and photographed with the use of a camera-equipped optical microscope. Histological descriptions of the oocyte stages were adapted from Forberg (1982) and Patino and Takashima (1995), with testicular descriptions following Brown-Peterson (2003).

Embryonic development was observed with a stereoscopic microscope, with photographs taken of each developmental stage. Embryo diameter, larvae length, and yolk

sac measurements were made with a caliper (to 0.1 mm). Descriptions of embryonic development follow the terminology of Martin and Drewry (1978).

RESULTS AND DISCUSSION

Twenty-three individuals of *O. beta* (16 females and 7 males) ranging from 44 to 220 mm SL (2.4 to 504.1 g WW) were used in the histological, macroscopic, and reproductive examinations. We consider *O. beta* to be a resident species within the Tecolutla estuary based on the presence of juveniles, adults, and nests containing eggs. This differs from the ecological category assigned by Castro-Aguirre (1978) who described *O. beta* as a euryhaline species with a marine component.

Male reproductive system

The testes of *O. beta* are elongate bodies with a white-yellow color and are situated on both sides of the spinal column and attached to the swim bladder by a delicate mesentery. The testes are covered with a thin and poorly vascularized tunica albuginea. The sperm ducts are thin and connected posteriorly to the urogenital complex. Histologically, the testes can be classified as a lobular type, with each lobule containing a series of spermatocysts. Spermatogenesis of *O. beta* is similar to other teleosts; spermatogonia, spermatocytes, spermatids, and spermatozoa were all observed in the testes. However, the occurrence of biflagellate spermatozoa (Figure 1A) observed in this species is unusual among teleosts (Lahnsteiner 2003).

Spermatogenesis appears to be a continuous process in *O. beta*. In contrast, Hoffman (1963a) reported that

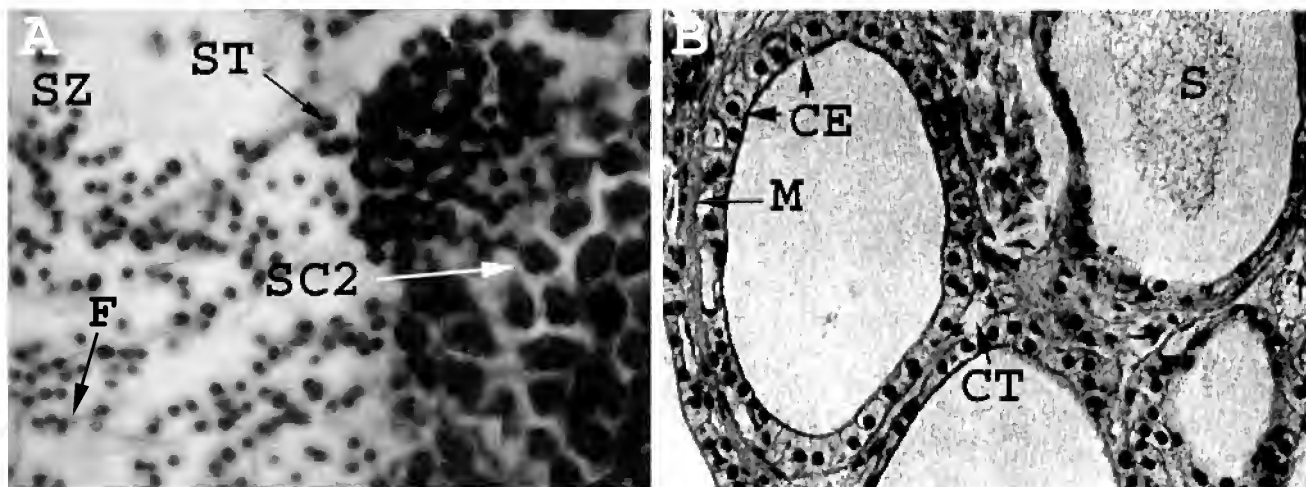Figure 1. Histological sections from *Opsanus beta*. A) Testis, showing various stages of spermatogenesis, including spermatozoa (SZ), secondary (SC2) spermatocytes and spermatids (ST). Note the double flagella on some spermatozoa (F), 40x in phase contrast. B) Septae from part I of the accessory gland consisting of cubic epithelial tissues (CE). Note the secretion (S), connective tissue (CT) and muscular fiber (M), 20x.

spermatogenesis completely ceased in male *O. tau* that had a large amount of spermatozoa stored in the testis. We did not observe a total cessation of spermatogenesis in *O. beta*. Whereas few spermatocysts were present in individuals collected in September and November, the lobules in these fish contained large amounts of spermatozoa, corresponding to the regression maturational class of Brown-Peterson (2003).

The accessory glands of *O. beta*, present only in males, are large, fan-shaped paired organs with a spongy appearance. The glands usually have a hyaline, orange color with septa visible under transmitted light. They are situated in the posterior part of the abdominal cavity and are joined to the sperm ducts. The glands have 3 sections that differ microscopically. The section closest to the sperm duct is formed of very thin septa characterized by a layer of cubic or flat epithelial cells and a basal sheet of thin and compact connective tissue containing fibers of smooth muscle (Figure 1B). This section is not highly vascularized, but the blood vessels present are relatively large. The internal parts of the septa have secretions that are PAS and aldehyde-fuscia positive, indicating the presence of mucopolysaccharides and mucins (Gomori 1952). Although spermatozoa can be found in septa closest to the sperm ducts, this is not a common occurrence and indicates the accessory glands do not store mature sperm.

The second region of the gland is formed by larger septa, covered with a thick glandular epithelium consisting of 6–7 layers. This tissue is highly vascularized, and some secretions can be observed. The basal sheet is connective tissue with fibers of smooth muscle surrounding each one of the septa. The most distal region of the gland contains smaller septa and packets of 1–2 layers of highly convoluted cubical or columnar glandular epithelium, with nuclei undergoing active protein synthesis. In this region, there is reduced vascularization, but the blood vessels present are of greater diameter than in other regions. All septa have a basal cover of connective tissue with smooth muscle that is thinner than in the middle region. Finally, this region of the gland has nodules appearing to be formed by lymphoid tissue.

These accessory glandular structures have been called accessory glands, seminal glands, or seminal vesicles by various authors (Sundararaj 1958, Fishelson 1991, Lahnsteiner et al. 1990), and the accessory glands observed in *O. beta* are similar to those reported for *O. tau* (Hoffman 1963b). Similar accessory glands are found in male fishes within the Blenniidae, Gobiidae, Clariidae, Bagridae, Tripterygiidae (Fishelson 1991), Heteropneustidae (Sundararaj 1958), Haenopsidae (Patzner 1991) and Opistognathidae (Rasotto 1993). However, the accessory glands present in the genus *Opsanus* are highly complex. Hoffman (1963b) reported that the glandular structure is divided into 4 different sections in *O. tau*, but we found only 3 sections in *O. beta*. It was not possible to establish the role of the accessory glands based on their position and development. However, some authors have proposed various functions for the glands and their secretions in other fishes. These include giving viability and motility to the spermatozoa (Sundararaj 1981 and references therein), increasing the seminal fluid viscosity and fulfilling phagocytic functions (Lahnsteiner et al. 1990), acting in nest formation (Fishelson 1991), serving as a place for sperm storage and maturation (Miller 1984), encouraging fertilization (Hoffman 1963b), and producing steroids that act like pheromones (De Jonge et al. 1989). It is possible that in *O. beta*, the glands fulfill one or more of these functions at the same time. The 3 sections of the glands could each produce a different type of secretion with different functions similar to that observed in *O. tau* (Hoffman 1963b). Detailed histochemical studies are necessary to reveal the exact composition of the glandular secretions and their possible functions in this species.

Oocyte maturation and spawning

The ovaries of immature females are a pair of thin, small, white sacks. When mature, the ovaries acquire an orange-yellow coloration, and the large oocytes are easily visible. Microscopically, the oocytes show asynchronous development. Pre-vitellogenic oocytes in the chromatin nucleolar, early perinucleolar, late perinucleolar, and cortical alveolar stages were observed in all but the smallest specimens. Vitellogenic oocytes in the primary, secondary, and tertiary stages were also observed. Asynchronous oocyte development, such as that observed in *O. beta*, is characteristic of fish that can spawn multiple times during the reproductive season (Brown-Peterson 2003). Oocytes in the tertiary vitellogenesis stage are fully mature, with a mean diameter of 3.28 mm. Ovulated oocytes had a mean diameter of 3.5 mm. Oocytes in the nuclear migratory and ovulatory stages were observed in *O. beta*, but oocytes undergoing germinal vesicle breakdown were not seen, likely due to the short duration of this stage.

Opsanus beta appears to have an extended reproductive season in the Tecolutla estuary. Females with mature oocytes were found from April through November, suggesting an 8 month reproductive season. In Pensacola, Florida, Allee (1998) noted spawning in May and September in *O. beta*. Nearly ripe males were found in March and June in Cedar Key, Florida, and a sexually mature female was taken in September (Reid 1954). This species also has relatively low batch fecundity: the largest
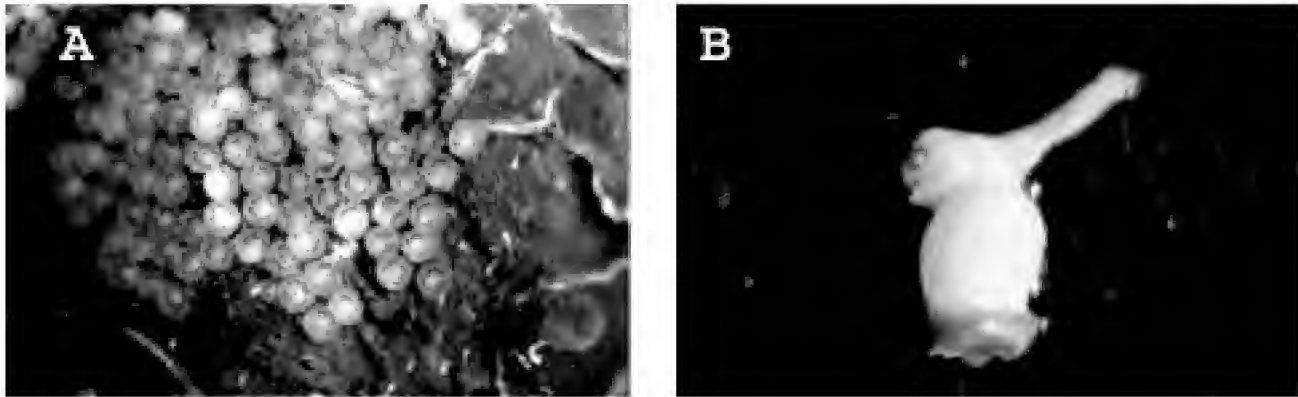
Figure 2. A) Nest of *Opsanus beta* eggs showing substrate typical of nests. Note the embryos are in different stages of development, suggesting at least two females spawned eggs in this nest. B) Larva of *Opsanus beta* with ocular pigment.

female captured (192 mm SL in April) contained 518 mature oocytes in the ovaries; a 141 mm SL female captured in October had 176 mature oocytes in the ovaries whereas the ovaries of the smallest mature female (111 mm SL, captured in November) had only 79 mature oocytes. The relatively low batch fecundity of *O. beta* is characteristic of this family (Breder 1941; Collette and Ruso 1981). However, low batch fecundity is offset by male parental care, which increases the survival probability of offspring. Additionally, the eggs are demersal and attached to submerged objects, which facilitates parental care. This reproductive strategy is typical for batrachoids (Breder and Rosen 1966) and was observed in the field.

Egg clutches of 2 *O. beta* were found in nests in April 1996 and May 1997 with a total of 350 and 412 eggs, respectively. One of these nests was in a cluster of oyster shells and another in a boot, suggesting *O. beta* will use any firm, relatively protected substrate as a nesting site. The eggs were spherical, orange colored, lacked oil droplets, and adhered to the substrate by an adhesive disc. Egg diameters varied between 2.1 and 4.6 mm, with a mean of 3.5 mm. The number of eggs found in the nests is greater than the batch fecundity of a single individual, suggesting that more than one female may spawn in the same nest. Indeed, a nest of eggs showed embryos in different developmental stages (Figure 2A), supporting this theory.

Embryonic and larval developmental

Various stages of early embryonic development, including the 8-, 16-, 32-, and the 64-cell stages, were observed among a recently spawned clutch of eggs. Unfortunately, these died before we could observe the morulation and gastrulation stages. However, a second clutch containing eggs in more advanced developmental stages was collected. In the late embryo stage, the yolk sac retained its spherical shape with the embryo located on the surface of the yolk sac opposite the adhesive disc. Two stages of larval development were also observed in hatched eggs. The first stage was characterized by the yolk sac beginning to lose its round shape. The larvae were attached to the yolk sac and did not have ocular pigment. Larvae in this stage ranged in size from 4.1 to 7.0 mm TL, with the yolk sac measuring 2.9 to 3.7 mm wide and 2.9 to 6.0 mm long. In the second stage, the eye acquired pigmentation and the yolk sac began to shrink and acquire a cylindrical shape (Figure 2B). Larvae in this stage were 5.4 to 7.7 mm TL and the yolk sac was 2.8 to 7.1 mm long and 2.5 to 4.0 mm wide.

Breder (1941) established that *O. beta* spawn between February and March in Florida. In the Tecolutla estuary, we observed spawning from March through May during the current study and have since seen toadfish nests in June (Martinez-Perez, personal observation). The development of large eggs and parental care in the toadfishes may be a response to environmental conditions. The estuaries in which these fish live have rapid fluctuations in temperature and salinity. Thus, resident fishes such as *O. beta* have developed strategies to increase reproductive success under these dynamic conditions.

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Helminths from *Dormitator maculatus* (Pisces: Eleotridae) in Alvarado Lagoon, Veracruz, Mexico, and Supplemental Data for *Clinostomum complanatum* Rudolphi, 1814 from *Egretta caerulea* (Aves: Ardeidae)

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HELMINTHS FROM *DORMITATOR MACULATUS* (PISCES: ELEOTRIDAE) IN ALVARADO LAGOON, VERACRUZ, MEXICO, AND SUPPLEMENTAL DATA FOR *CLINOSTOMUM COMPLANATUM* RUDOLPHI, 1814 FROM *EGRETTA CAERULEA* (AVES: ARDEIDAE)

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ABSTRACT Fishes are important hosts of helminths with aquatic life stages, yet little information is available on host-parasite relationships in tropical low salinity ecosystems. In this paper we report helminth parasites of the fat sleeper, *Dormitator maculatus,* in the Alvarado lagoon system, Veracruz. Mexico. Four parasite species were recorded from *D. maculatus,* including trematode metacercariae of *Clinostomum complanatum,* as well as nematode larvae of *Spyroxis* sp. and *Camallanus* sp. and adults of *Neochinorhynchus golvani.* In addition, we obtained adult *C. complanatum* from the esophagus of the little blue heron, *Egretta caerulea. Dormitator maculatus* is a new host for all helminth species reported, and the Alvarado lagoonal system is a new location for these parasite relationships. The prevalence of the 2 most commonly occurring parasites, *C. complanatum* and *N. golvani,* was high throughout the year (> 60% and > 43%, respectively). Intensity of infection was highest for *C. complanatum* in May (92 worms/host) and for *N. golvani* in October 1993 (33.8 worms/host). The trophic position and habits of *D. maculatus* contributes to recruitment of trematode and nematode larval stages.

INTRODUCTION

Fishes represent an important component of the biomass and biodiversity within the ecosystem at Alvarado Lagoon in Veracruz, Mexico. The estuary serves as a rich feeding ground for both resident and migratory fishes, creating an ideal habitat for a variety of parasitic helminths to flourish. The fat sleeper, *Dormitator maculatus*, is an important species within the assemblage of fishes from Alvarado Lagoon that also includes mugilids, centropomids, ariids, and cichlids. *Dormitator maculatus* inhabits low salinity (0–21 psu) coastal areas of the subtropical and tropical western Atlantic between North Carolina (USA) and southeastern Brazil (Fisher 1978). While previous studies have documented the parasite assemblage of *D. maculatus* from temperate areas, none has done so in a highly productive tropical estuary like Alvarado Lagoon, an estuary with relatively stable environmental conditions during much of the year. The helminths of fat sleepers include trematodes, cestodes, acanthocephalans, nematodes, and leeches at various localities throughout its range (see Yamaguti 1971, Hoffmann 1999). However, some of these helminths, such as *Clinostumum* spp. Leidy, 1865 are present only in *D. maculatus* as metacercarie, making identification of species based solely on morphology difficult. The definitive hosts for *Clinostomum* spp. are piscivorous birds, and various egrets and herons have been reported as hosts for adults at other localities from Veracruz state (Hernández 1996). Thus, in order to have a complete understanding of the helminthofauna of *D. maculatus,* parasites in the definitive host must also be examined.

In this study, our intention is to describe the helminths of *D. maculatus* in Alvarado Lagoon. Additionally, the prevalence and intensity of the dominent helminths are quantified.

MATERIALS AND METHODS

Helminth collections

A total of 184 *D. maculatus* were collected from the mouth of Rio Papaloapan in Alvarado Lagoon, Veracruz, Mexico (18°45.825 N, 95°49.137W) during monthly samples between October 1993 and October 1994. Each sample consisted of between 16 and 34 fish. The fish were captured with a dip net and transported live in river water to a field station in Alvarado where identification was confirmed as *D. maculatus* using Castro (1978) and Hubbs et al. (1991). The mouth, esophagus, stomach, intestine, mesentery, and liver of each fish were thoroughly examined for helminths. Each organ was removed and examined in a petri dish with 0.65% saline solution, using a stereoscopic dissecting microscope. Helminths were removed from tissues using a small paintbrush and placed in 0.65% saline solution prior to fixation. Fixation technique varied depending on the type of helminth. During the course of collecting *D. maculatus,* 2 little blue herons, *Egretta caerulea,* were also collected from Alvarado Lagoon. The

mouth and esophagus of each bird was examined, and adult specimens of *Clinostomum* sp. were collected using the same techniques as with fish. Trematodes were fixed in Bouin's solution in the cold with cover slip pressure for 24 h. The trematodes were then placed in distilled water which was slowly replaced with 70% ethanol. Trematodes were preserved in 70% ethanol until staining. Trematodes were stained with either Mayer's Paracarmine or Harris's Hematoxylin, cleared in methyl silicilate, and mounted on glass slides in Canada balsam. In contrast, live acanthocephalans were placed in 4 °C distilled water for 5 to 8 h in order to facilitate the eversion of the proboscis. They were then transferred to Bouin's solution for 24 h and finally preserved in 70% ethanol following the above procedures. Acanthocephalans were stained and mounted on glass slides using the same procedures described for trematodes. The cuticle was punctured to allow stain to penetrate the specimen. Nematodes were fixed in 50–60 °C 70% ethanol and preserved in unheated 70% ethanol. Temporal preparations of nematodes were made by mounting them on glass slides in Amman's Lactophenol.

Parasites were identified using Yamaguti (1961), Hoffman (1970), Petrochenko (1971), and Chabaud (1975). All specimens were examined using a compound light microscope, and drawings were made with the aid of a camera lucida. Measurements (mm) are given as a range followed by a mean in parentheses. Specimens of all taxa currently reside in the Colección de Helmintos del Instituto de Biología, UNAM (#1600, 1601, 3077, 3078, and 3079).

RESULTS

Taxonomic descriptions

Trematoda
Clinostomidae Lühe, 1901
Clinostomum complanatum Rudolphi, 1814
(Figure 1)

Description: Metacercaria (Figure 1B, Table 1): data based on 10 specimens. Metacercaria encysted in liver or mesentery; cyst white to pale-yellow, subspherical, 0.86–2.63 (2.03) long, 0.66–1.93 (1.33) wide, thick walled. Metacercaria white and yellow in life, moving vigorously when removed from cyst. Body unspined, 2.10–6.25 (3.87) long, 0.75–1.80 (1.10) wide at mid-body. Oral sucker subterminal, 0.27–0.32 (0.30) wide, surrounded by a cephalic ring. Prepharynx distinct, pharynx small, giving rise to 2 intestinal crura; crura lateral, running the length of the body, terminating near posterior end of body, walls projecting irregularly along lengths. Ventral sucker

0.47–0.85 (0.63) wide, lying 0.27–0.80 (0.54) posterior to the oral sucker. Ratio of oral sucker to ventral sucker width 1:1.62–2.5 (1:2.14). Reproductive structures in hindbody, incompletely developed; testes tandem; anterior testis, triangular, trilobed, 0.12–0.40 (0.25) long, 0.24–0.56 (0.36) wide; posterior testis similar in shape to anterior one, slightly larger, 0.12–0.40 (0.24) long, 0.28–0.46 (0.39) wide; ovary submedian between testes, closer to anterior testis, subspherical, 0.08–0.20 (0.15) long, 0.06–0.12 (0.09) wide.

Adult (Figure 1A, Table 2): data based on 9 specimens from the mouth and esophagus of 2 specimens of *E. caerulea*. Body unspined, reddish in color in life, sluggish in comparison to metacercaria, 3.9–6.15 (5.1) long, 1.20–1.50 (1.38) wide near mid-body. Oral sucker subterminal, 0.29–0.34 (0.31) wide, situated within a depressed cephalic ring. Prepharynx distinct, pharynx small, giving rise to 2 intestinal crura; crura lateral, running length of body, walls irregular along lengths, connecting to excretory vesicle at posterior end of body. Ventral sucker 0.62–1.02 (0.834) wide. Ratio of oral sucker to ventral sucker width 1:2.1–3.03 (1:2.68). Testes tandem, triangular; anterior testis 0.32–0.54 (0.42) long, 0.56–0.76 (0.62) wide; posterior testis 0.30–0.52 (0.40) long, 0.58–0.80 (0.68) wide. Cirrus sac cresent-shaped, thick walled, lying dextral to anterior testis, containing twisting seminal vesicle filled with sperm, prostatic duct surrounded by prostatic cells, and muscular ejaculatory duct; ejaculatory duct leading to genital atrium; genital atrium and ejaculatory duct eversible. Ovary submedian between testes, 0.20–0.32 (0.26) long, 0.12–0.20 (0.155) wide. Mehlis' gland lying next to ovary and anterior to posterior testis. Vitelline follicles filling most of hindbody, reaching anterior to mid-level of ventral sucker. Uterus intercaecal, extending anterior from ovarian level, reaching ventral sucker level, turning, and extending back to genital atrium, containing unembryonated, operculate eggs 0.10–0.12 (0.11) long, 0.05–0.07 (0.06) wide; genital atrium opening through submedian genital pore at level of anterior testis. Excretory vesicle V-shaped, indistinct, pore dorso-terminal.

Intermediate host: *Dormitator maculatus*
Site within intermediate host: Liver and mesenteries
Definitive host: *Egretta caerulea*
Site within definitive host: mouth and esophagus
Locality: Mouth of Rio Papaloapan, Alvarado Lagoon, Veracruz, Mexico.
Specimens deposited: UNAM No. 1600 (adult), 1601 (metacercaria)

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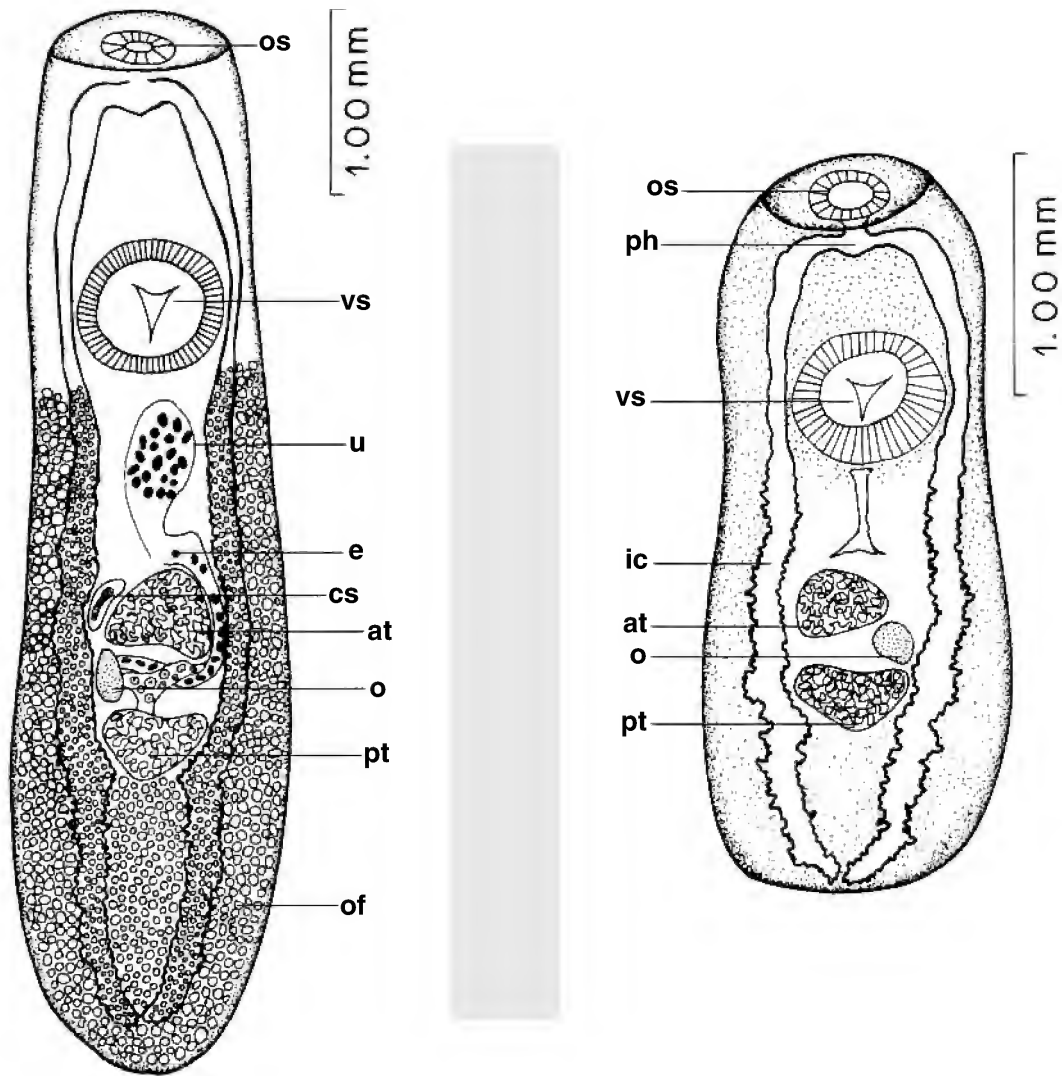
Figure 1. *Clinostomum complanatum* from *Dormitator maculatus* collected in Alvarado Lagoon, Veracruz. A) Adult. B) Metacercariae. vs = ventral sucker, os = oral sucker, ph = pharynx, of = ovary follicle, ic = intestinal caeca, at = anterior testis, pt = posterior testis, o = ovary, cs = cirrus sac, u = uterus, e = eggs.

Acanthocephala
Neoechinorhynchidae Ward, 1917
Neoechinorhynchinae Travassos, 1926
Neoechinorhynchus golvani **Salgado-Maldonado, 1978**
(Figure 2)

Description: Data based on 20 adult specimens (10 males and 10 gravid females) from mucosa of anterior intestine. Adult females much larger than adult males. In both sexes, ovoid body, small apical cylindrical proboscis, 3 rows of hooks, apical row, medial row, and basal row, with 6 hooks each one; apical hooks much larger than others. Neck spindle shaped, not well defined; continuous with trunk, but slender at anterior end. Body wall thick, 5 gigantic nuclei on the dorsal surface and one on the ventral surface. Sac shaped proboscis receptacle with simple wall;

inserts in body wall base. Lemnisci sac-like with thick distal parts, longer than the proboscis receptacle length.

Body length (including proboscis) 1.21–3.50; trunk length 1.12–3.41. Maximum body width 0.375–1.17. Proboscis length 0.06–0.09, width 0.04–0.07. Apical proboscis hooks robust, 0.040–0.057 long, 0.006–0.008 wide at base. Medial hooks small, 0.012–0.014 long, 0.003–0.004 wide at base. Basal hooks small, 0.014–0.016 long, 0.003–0.004 wide. Proboscis receptacle length 0.15–0.31, width 0.05–0.10.

Male reproductive system consists of 2 tandem, contiguous testes, posterior testis touches cement gland which leads to the seminal vesicle, elongate, with 2 cement reservoirs (irregularly bulging sections, full of cement from the gland). Seminal vesicle leading to copulatory bursa. Saefftigen's pouch connects to proximal end of the copulatory bursa.

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TABLE 1

Morphometric features of *Clinostomum complanatum* metacercariae. Values are presented in mm as mean with range in parentheses. *n* = number of individuals, ND = no data.

Morphometric feature		This Study (*n* = 10) Mean (min–max)	Mejia 1987 (*n* = 8)	Kagei et al. 1984 (*n* = ND)
Cyst	Length	2.030 (0.860–2.630)	2.00	2.00
	Width	1.330 (0.660–1.930)	—	—
Body	Length	3.870 (2.300–6.050)	(4.170–5.070)	(4.680–8.240)
	Width	1.105 (0.750–1.800)	(1.150–2.30)	(1.390–2.090)
Oral sucker	Diameter	0.297 (0.270–0.320)	0.279	(0.277–0.493)
Ventral sucker	Diameter	0.630 (0.470–0.850)	(0.740–0.860)	(0.889–1.540)
Distance between suckers		0.545 (0.270–0.800)	0.900 (0.600–0.70)	—
Sucker ratio		1:2.14 (1:1.6–2.6)	1:2.0	—
Anterior testis	Length	0.247 (0.120–0.400)	—	—
	Width	0.362 (0.240–0.560)	0.520 (0.450–0.560)	—
Posterior testis	Length	0.244 (0.120–0.400)	—	—
	Width	0.386 (0.280–0.600)	0.490 (0.350–0.508)	—
Ovary	Length	0.155 (0.080–0.200)	0.110	—
	Width	0.095 (0.060–0.120)	0.100 (0.090–0.110)	—

Female reproductive system with great number of ovarian balls distributed in entire trunk cavity. Half-moon shaped eggs scattered inside the ovarian balls, measuring 0.028–0.031 (0.029) long, 0.008 (0.008) wide. Genital organs small, occupying posterior fifth of the trunk, measuring 0.29–0.33 (0.36) long. Uterine bell sub-spherical communicating with a short thick uterus; uterus leading to vagina and gonopore.

Host: *Dormitator maculatus*
Site in host: anterior intestine
Locality: Mouth of the Papaloapan River, Alvarado Lagoon, Veracruz, Mexico
Collection Dates: October 1993–October 1994.
Specimens deposited: UNAM 3077

TABLE 2

Morphometric features of *Clinostomum complanatum* adults. Values are presented in mm as mean with range in parentheses. *n* = number of individuals, ND = no data.

Morphometric feature		This Study (*n* = 9) Mean (min–max)	Lo et al. 1982 (*n* = ND)	Hernández 1995 (*n* = 13)
Body	Length	5.100 (4.050–6.150)	(3.800–9.000)	4.615
	Width	1.380 (1.200–1.550)	(1.300–2.000)	1.260
Oral sucker	Diameter	0.310 (0.280–0.340)	(0.250–0.440)	0.286
Ventral sucker	Diameter	0.839 (0.620–1.020)	(0.600–0.800)	0.656
Distance between suckers		0.788 (0.620–1.020)	—	—
Sucker ratio		1:2.68 (1:2.1–3.03)	—	1:2.55
Anterior testis	Length	0.423 (0.320–0.540)	—	0.220
	Width	0.623 (0.560–0.76)0	—	0.295
Posterior testis	Length	0.396 (0.300–0.520)	—	0.260
	Width	0.685 (0.580–0.800)	—	0.316
Ovary	Length	0.260 (0.200–0.320)	0.331	0.061
	Width	0.115 (0.120–0.200)	0.231	0.066
Cirrus sac	Length	0.403 (0.320–0.500)	—	(0.212–0.625)
	Width	0.145 (0.120–0.180)	—	(0.125–0.275)
Egg	length	0.108 (0.100–0.120)	0.1198	(0.100–0.112)
	Width	0.058 (0.050–0.070)	0.0721	(0.050–0.070)
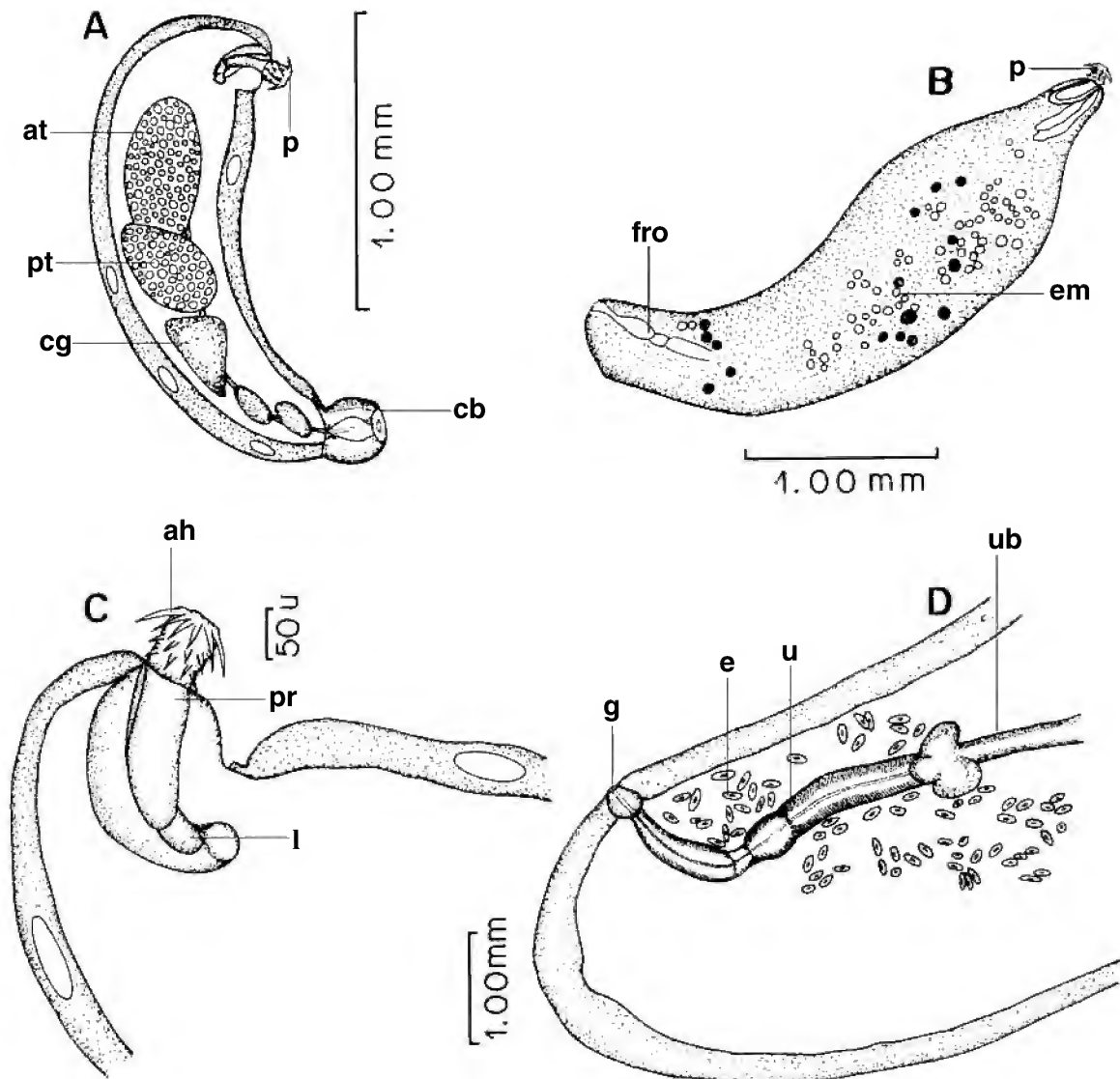
Figure 2. *Neoechinorhynchus golvani* from *Dormitator maculatus* in Alvarado Lagoon, Mexico. A) adult male. B) gravid female. C) male anterior end. D) female posterior end. fro = female reproductive organs, cb = copulatrix bursa, pr = proboscis receptacle, ub = uterine bell, g = gonopore, ah = apical hooks, cg = cement gland, e = eggs, l = lemnisci, em = egg mass, p = proboscis, at = anterior testis, pt = posterior testis, u = uterus.

Nematoda
Gnathostomatidae Raillliet, 1895
Spiroxys sp. (larva)
(Figures 3A, B)

Description: Larvae described based on 7 specimens removed from thin-walled translucent host capsules located on muscular stomach wall of host. Worms white or opaque in host capsules, moved sluggishly when liberated, relaxed and white when fixed. Fixed body cylindrical, uniform thickness along most of the body length, with pointed ends; cuticle transversely grooved.

Larvae: Body 0.25–1.77 (1.39) long, 0.33–0.05 (0.04) wide. Bucal capsule confined to cephalic region, with one pair of internal lips forming a triangle; internal lips 0.016–0.033 (0.022) long, surrounded by 2 pseudolabiae (lateral lips); pseudolabia 0.006–0.010 (0.008) long. The oral opening lacking an oral vestibule. Digestive tract consisting of esophagus, intestine, rectum, and anus. Esophagus divided into muscular anterior portion and glandular posterior portion, both portions measured together 0.133–0.425 (0.233) long. The intestine and short rectum together measure 0.223–1.24 (1.03) in length. Caudal end of the body conical, anus opens 0.053–0.068 (0.062) from the terminal end of the worm. No reproductive structures present.

Host: *Dormitator maculatus*
Site in host: muscular wall of stomach

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Figure 3. Parasite nematode larvae. A) *Spiroxys* sp from *Dormitator maculatus*. **B)** *Spiroxys* sp. anterior end, v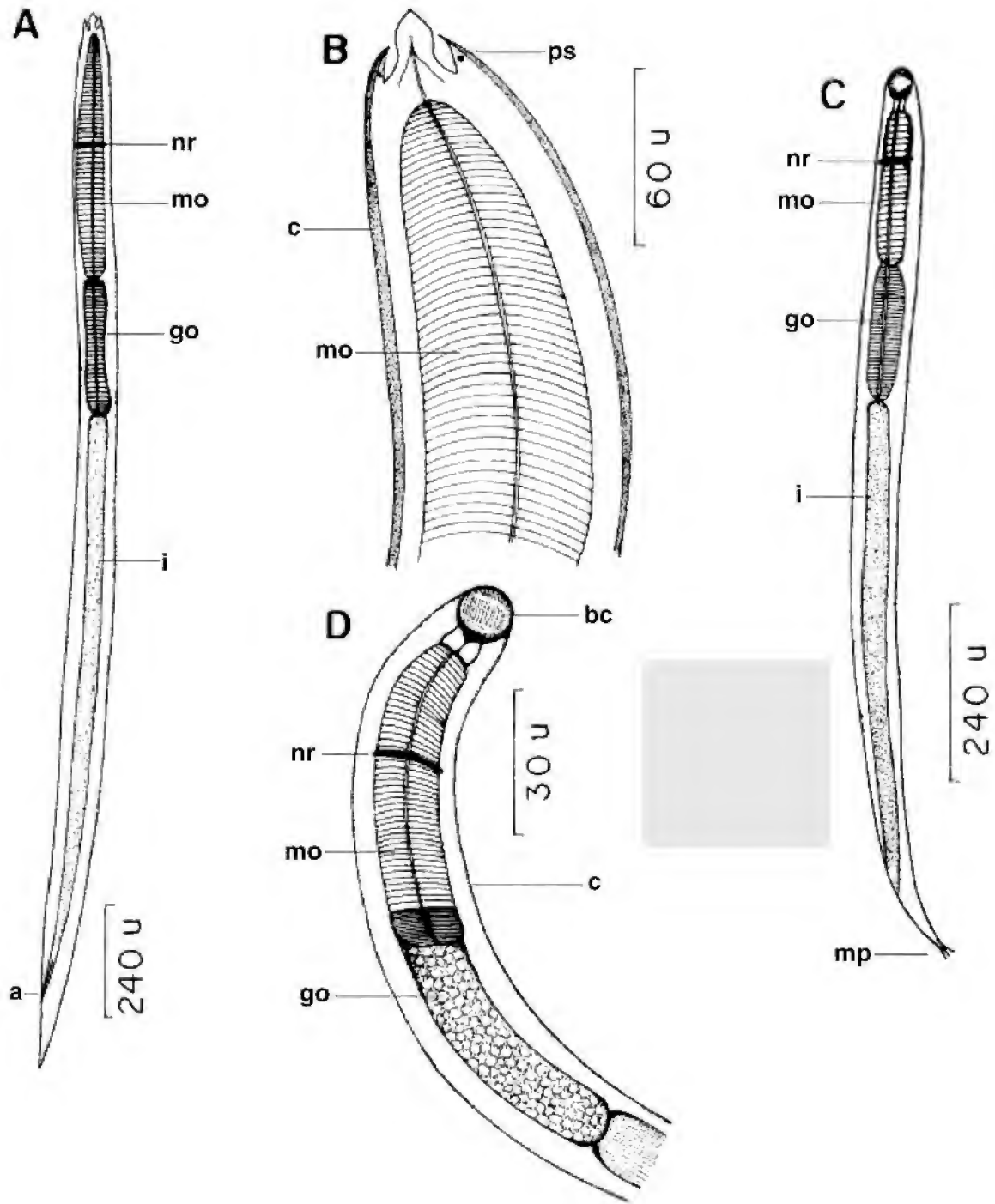entral view. **C)** *Camallanus* sp. **D)** *Camallanus* sp., anterior end, dorsal view. a = anus, nr = nervous ring, c = cuticle, bc = bucal cavity, go = gland oesophagus, mo =muscle oesophagus, i = intestine, mp = mamiliform processes, ps = pseudolabiae.

Locality: Mouth of Rio Papaloapan, Alvarado Lagoon, Veracruz, Mexico
    Date of collection: April–May 1994
    Specimen deposited: UNAM 3078

Camallanidae Railliet and Henry, 1915
Camallanus **Railliet and Henry, 1915**
Camallanus **sp. (stage 3 larva)**
(Figures 3C, D)

Description: Descriptions based on 9 larval specimens collected from the posterior intestine (near the anus) of *D. maculatus*. Worms very small, stretch easily, move slowly on the mucosa, appear yellow, clear, or pinkish. Anterior part rounded, comprises bucal capsule; divided into dorsal and ventral valves with ornamentations surrounding the interior margins of longitudinal grooves; continues into muscular and glandular portions of esophagus. The posterior end of the worm tapers to a point with 3 processes. No reproductive structures visible/developed.

    Larvae: Body 0.933–1.075 (1.051) long, 0.050–0.066 (0.058) wide. Bucal capsule 0.054–0.058 (0.056) long, 0.033–0.037 (0.034) wide. Muscular esophagus 0.166–0.200 (0.181) long, 0.037–0.066 (0.044) wide. Glandular esophagus 0.116–0.158 (0.138) long, 0.033–0.058 (0.038) wide. Anus opens a distance of 0.041–0.057 (0.047) from the terminal body end. Terminal processes measure 0.008–0.012 (0.010) long.

    Host: *Dormitator maculatus*
    Site in host: posterior intestine
    Locality: Mouth of Rio Papaloapan, Alvarado Lagoon, Veracruz, Mexico
    Date of collection: April 1994
    Specimen deposited: UNAM 3079

Prevalence and intensity of parasites

Monthly values of infection parameters for *C. complanatum* and *N. golvani* are shown in Table 3; nematode larvae *Camallanus* sp. and *Spiroxys* sp. were not considered because they were only rarely collected. The prevalence of *D. maculatus* infected with *C. complanatum* was highest in November (90%) and May (94.4%) and lowest in December (60%), while the highest prevalence of hosts infected with the acantocephalan *N. golvani* was in July (100%) and October 1993 (90.9%) and lowest in February (43.7%). The intensity of infection with *C. complanatum* metacercariae was also highest in May (92 worms/infected fish) and least in December (18.7 worms/infected fish). The highest intensity of infection with *N. golvani* was in October 1993 and October 1994 (33.8 and 32.4 worms/infected fish, respectively) and lowest in February (3.1 worms/infected fish). A correlation analysis showed a significant, positive relationship in the intensity of infection between *C. complanatum* and *N. golvani*, although there was a relatively low association between intensity of the 2 parasites (Pearson $r = 0.36$, $P < 0.05$).

DISCUSSION

Clinostomum complanatum

Clinostomum Leidy, 1856 contains a group of species that utilizes freshwater snails as first intermediate host; freshwater fishes, frogs, salamanders, and some snakes as secondary intermediate hosts; and piscivorous birds and occasionally mammals as definitive hosts (Nigrelli 1936, Lo et al. 1981, 1982). Typical avian hosts include herons and egrets (Ardeidae) (Yamaguti 1971). The specimens from *D. maculatus* and *E. caerulea* from Alvarado Lagoon are consistent with *C. complanatum* Rudolphi, 1814 because the ovary is intertesticular, the sucker ratio is correct, the cecal projections are not well pronounced, and the

TABLE 3

Monthly infection variables of *Dormitator maculatus* helminths from the Alvarado Lagoon system. *s* = standard deviation

Month	*Clinostomum complanatum*		*Neoechinorhynchus golvani*	
	Prevalence	Intensity	Prevalence	Intensity
October 93	72.7	58.0	90.9	33.8
November 93	90.9	61.0	78.7	22.3
December 93	60.0	18.7	70.0	12.0
February 94	81.2	44.8	43.7	3.1
April 94	89.4	31.0	57.8	18.9
May 94	94.4	92.0	83.3	14.6
July 94	81.8	25.7	100.0	12.3
October 94	73.5	69.6	76.4	32.4
Mean ± *s*	80.5 ± 10.7	50.1 ± 23.2	75.1 ± 16.8	18.7 ± 9.8

genital pore is submedial and lateral to the anterior testis. Even more importantly, the cirrus sac is intertesticular and contains a twisting seminal vesicle in adults. In addition, body size, egg size, lack of metacercarial body spines, and the use of a freshwater or estuarine fish as an intermediate host are all traits of *C. complanatum*. Dimensions for material from the present study is compared to dimensions reported by other authors for metacercaria (Table 1) and adults (Table 2) of *C. complanatum* in Mexico. In all cases, the range of values for morphometric measurements in this study concurs with previous descriptions.

It should be noted that there is some disagreement in the literature regarding the taxonomy of *C. complanatum* and *C. marginatum* Rudolphi, 1819. Dowsett and Lubinsky (1980), after reviewing the works of various authors and available geographic information, considered the 2 species synonomous. Nevertheless, Lo et al. (1982) disregarded this synonymy and considered the position of the genital pore, as well as body length and width, to be a useful and important feature for separating these 2 species. Thus, some North American authors consider metacercariae from North American freshwater fishes to be *C. marginatum* and those from North American frogs and Asian and European fishes to be *C. complanatum*. However, only *C. complanatum* has been reported in Mexico (Lamothe-Argumedo et al. 1996, Salgado-Maldonado et al. 1997, Scholz and Aguirre Macedo 2000), with this identification based on the morphological features defined by Lo et al. (1982). The material we describe from *D. maculatus* is consistent with previous descriptions from Mexican fishes and is thus positively identified as *C. complanatum*. This taxonomic discrepancy may be solved using genetic techniques such as 18S ribosomal RNA gene sequences, which was successfully used to clarify acantocephalan phylogenetic relationships (García-Varela et al. 2000).

Of all the helminths reported from *D. maculatus* in this study, only *C. complanatum* has a worldwide distribution. The definitive hosts for this species (piscivorous birds) have presumably introduced this parasite throughout its cosmopolitan distribution while traveling along migratory pathways. The parasite is able to survive if the proper environmental conditions are present and if the proper intermediate hosts are available (Van Cleave and Mueller 1934, Jiménez 1993).

At least 3 other species of *Clinostomum* have been reported from Mexico. Bravo-Holis (1947) reported *C. heluans* Braun, 1899 from *Ardea herodias* and *C. intermedialis* Lamont, 1920 from *Phallacrocorax penicillatum*, both from Nuevo Leon. More recently, Mejia (1987) reported *C. intermedialis* from *Goodea atripinnis* in Pátzcuaro Lake, Michoacán. *Clinostomum complanatum*

may be differentiated from *C. heluans* by having a much smaller adult body size (3.9–6.5 compared to 20.7–26.1 in length). *Clinostomum complanatum* differs from *C. intermedialis* by being slightly smaller (3.9–6.6 compared to 6.6–11.1 in length) and by having the cirrus sac located slightly more anterior (at the level of the anterior testis rather than at the level of the ovary). Amaya and Duran (1996) reported the third species, which they identified as *C. complanatum* from *D. maculatus*; however, metacercariae they described had body spines like *C. gigantecum* Agarwal, 1959. It is unlikely that the specimens described by Amaya and Duran (1996) are conspecific with *C. gigantecum* owing to the Indian distribution of that species, but it is likely that their specimens belong in a 4th, as of yet unidentified, species of *Clinostomum*. The presence of body spines precludes these specimens from being *C. complanatum*.

Metacercariae of *C. complanatum* have been reported from a great number of second intermediate host fishes. In Asia, including Japan, these hosts include: *Carassius carassius*, *Pseudogobio esocinus*, *Achelilognathus intermedia*, *Misgurnus fosilis anguillicuadatus*, and *Eupomotis gibosus* (see Lo et al. 1982) and *Carassius cuvieri*, *Cyprinus carpio*, *Rhodeos ocellatus*, *Cubitis anguillicaudatus*, *Hypomesus transpacificos*, *Lateolabrax japanicus*, and *Leuciscus hakonensis* (Aohagi et al. 1992a, 1993b, 1995). In Africa, *Serranochromis macrocephalus*, *Oreochromis mortimeri*, and *Tilapia rendalli* have been reported as hosts (Douèllou and Erlwanger 1993), and in North America, over 50 hosts are known. A few of the more common North American hosts include: *Perca flavescens*, *Aphredoderus sayanus*, *Micropterus dolomieu*, *M. salmoides*, *Ambloplites rupestris*, *Lepomis pallidus* (=*L. macrochirus*), *Catostomus commersoni*, and *Pimephales promelas* (Nigrelli 1936). In Mexico alone, *C. complanatum* has been reported from 28 species of freshwater fishes from 11 families including Cichlidae. Within Cichlidae, hosts are known from 10 different states in Mexico, and from Tabasco alone, cichlids host *C. complanatum* in 10 different bodies of water. The most commonly reported cichlid hosts in Mexico are *Cichlasoma cyanoguttatum*, *C. fenestratum*, *C. robertsoni*, *C. istlanum*, *C. pasionis*, *C. pearsei*, *C. synspilum*, *C. urophthalmus*, and *Petenia splendida* (Pineda-López 1985, Osorio et al. 1987, García et al. 1993, Galaviz-Silva et al. 1992, Segovia-Salinas et al. 1993, Peresbarbosa 1992, Peresbarbosa et al. 1994, Scholz et al. 1995, Pérez-Ponce de León et al. 1996, Salgado-Maldonado et al. 1997).

Adults of *C. complanatum* have been reported from the mouth and esophagus of piscivorous birds worldwide. In Asia and North America, species in *Ardea*, *Ardeola*,

Concroma, Mycteria, Egretta, Nycticorax, Larus, Buturides, Phalacrocorax, Pelecanus, Bubulcus, Botaurus, Plegadis, Gallinula, Podiceps, and *Ixobrychus* serve as hosts, and even humans have been reported as an accidental host (Lo et al. 1982, Aohagi et al. 1993a). In Mexico, Caballero y Caballero (1946) reported *C. complanatum* in *Butorides virescens* from Motozintla, Chiapas. Ramos (1995) reported the same species from *Egretta thula, Casmerodius albus,* and *Botaurus* sp. in Oaxaca, and Hernández (1996) reported *C. complanatum* in *Pelecanus erythrorhynchus* and *Rhynchops niger* from Tecolutla, Veracruz. The presence of adults in *E. caerulea,* as reported in this study, represents a new definitive host for *C. complanatum.* However, we cannot assume that the egrets are all infected by *D. maculatus,* as 16 species of frogs, known intermediate hosts of *C. complanatum,* are present in the Alvarado Lagoon area (Altamirano et al. 1996).

Campos (1992) reported a prevalence of 66% and an intensity of 2.3 worms/ host in *Gobiomorus dormitor* from Río Tecolutla, Veracruz, whereas the present study found a prevalence of 82.3% and intensity of 49.7 worms/host in *D. maculatus* from Alvarado Lagoon, in the same state as Río Tecolutla. Apparently, *D. maculatus* is a much better host for the parasite. It is possible that this is due to habitat selection by the fish. *Dormitator maculatus* is a sedentary benthic fish that lies semi-buried in mud in the littoral zone and feeds on detritus. In contrast, *G. dormitor* normally lies in wait to ambush prey under cover of vegetation in littoral zones that are thick with aquatic vegetation. Assuming infection by *C. complanatum* is influenced solely by ecological parameters and not by physiological ones, it is likely that these different niches convey different infection rates for fish (Yoshino 1989). The availability of *D. maculatus* as a host for these species is no doubt related to the trophic position of the fish, as discussed by Zander et al. (1993) in European aquatic ecosystems.

The results of this study suggest that *D. maculatus* is often infected by *C. complanatum* in Alvarado Lagoon, and that the sedentary behavior of the fish may increase the time of exposure to infective cercariae, causing greater prevalence of infection and abundance of parasites in this host. The process of infection starts with cercariae actively finding and penetrating the lamellae of the gill arch and then migrating to the heart or liver where they encyst (Chávez et al. 2003). The metacercariae are found in the celomic cavity on intestinal mesenteries (Galaviz-Silva et al. 1992). Although hydrobiid snails, a known host for the cercariae, are found in the diet of *D. maculatus* (Chávez 1998), the cercariae or cysts were never found in the digestive tract, suggesting cercariae infection is active, not passive.

Neoechinorhynchus golvani

The acanthocephalans examined in this study possessed a small proboscis that may appear spherical or almost cylindrical depending on the degree of contraction. The proboscis has 3 lines of hooks, each line having 6 hooks. The body trunk without is devoid of spines and has large hypodermal nuclei, and males have syncytial cement glands associated with the reproductive tract. Together, the presence of these features allows for the identification of this species in *Neoechinorhynchus* Hamann, 1892 (see Petrochenko 1971).

Neoechinorhynchus is a diverse genus within Acanthocephala, with nearly 75 described species that live in the intestine of marine and freshwater fishes in Asia, Europe, and North America (Amin 1985). In Mexico, *N. roseum* Salgado-Maldonado 1978 and *N. golvani* Salgado-Maldonado 1978 are morphologically similar. *Neoechinorhynchus golvani* differs from *N. roseum* by having a shorter organ of lemnisci and a smaller and narrower body trunk.

Neoechinorhynchus golvani has been reported from 4 different families of freshwater and brackish water fishes in Mexico and is a common acanthocephalan of fishes in Tabasco, Campeche, Yucatan, and Colima. Of these fishes, the cichlids are the most common hosts for *N. golvani.* Eleven species of cichlid, from 5 states (Campeche, Colima, Tabasco, Veracruz, and Yucatan) are known hosts (Salgado-Maldonado 1978, 1985, Osorio et al. 1987, Ramírez 1987, Pérez-Ponce de León et al. 1996, Salgado-Maldonado et al. 1997). In Veracruz, *Cichlasoma fenestratum* is host to *N. golvani* in Catemaco Lake (see Jiménez 1993), and *Centropomus parallelus* and *Dormitator maculatus* host the species in Alvarado Lagoon (Velazquez 1994, Cancela 1995, present study). Specimens examined in this study are slightly smaller than those reported in cichlids from Tabasco by Salgado-Maldonado (1985; Table 4). Nevertheless, the specimens are similar in internal configuration, and despite the slightly smaller measurements, the specimens from both locations are conspecific.

Cancela (1995) reported a prevalence of infection by *N. golvani* of 1.1% in *C. parallelus,* Trujillo (1995) reported 16.7% prevalence in *C. urophthalmus,* Velázquez (1994) reported 53.3% prevalence in *G. dormitor,* and, in our study, 76.1% of *D. maculatus* were infected. The maximum number of acanthocephalans present in a single fish was 114. These differences are probably due to the environmental conditions that may reduce or favor the likelihood of predation on the intermediate host. In the case of *D. maculatus,* the high prevalence and intensity of infection suggest a close association with large numbers of

TABLE 4

Morphometric features of *Neoechinorhynchus golvani* adults. Minimum and maximum values are presented in mm. *n* = number of individuals.

Morphometric feature		This study		Salgado 1985	
		Male (*n* = 10) min–max	Female (*n* = 10) min–max	Male (*n* =23) min–max	Female (*n* = 9) min–max
Total length		1.206–2.580	1.870–3.500	0.776–5.812	4.865–7.165
Trunk	Length	1.125–2.500	1.760–3.410	0.714–5.490	3.300–7.080
	Width	0.375–0.625	0.520–1.170	0.316–1.650	0.930–2.370
Proboscis	Length	0.070–0.090	0.060–0.090	0.049–0.083	0.065–0.098
	Width	0.040–0.060	0.050–0.070	0.052–0.083	0.070–0.098
Apical hooks	Length	0.040–0.050	0.040–0.057	0.039–0.057	0.039–0.052
	Width	0.006–0.008	0.006–0.008	0.005–0.007	0.005–0.007
Medial hooks	Length	0.012–0.014	0.012–0.014	0.013–0.020	0.015–0.026
	Width	0.003–0.004	0.003–0.004	0.002–0.005	0.002–0.007
Basal hooks	Length	0.014–0.016	0.014–0.016	0.010–0.015	0.013–0.020
	Width	0.003–0.004	0.004	0.002	0.002–0.005
Proboscis receptacle	Length	0.150–0.290	0.150–0.310	0.169–0.390	0.285–0.397
	Width	0.050–0.090	0.050–0.100	0.052–0.150	0.065–0.171
Reproductive apparatus	Length	0.550–1.550	0.290–0.330	0.387–3.810	0.795–0.897
Copulatrix bursa	Length	0.083–0.125	—	—	—
	Width	0.075–0.116	—	—	—
Eggs	Length	—	0.028–0.031	—	—
	Width	—	0.008	—	—

infected intermediate hosts, perhaps related to the productive nature of Alvarado Lagoon.

Spiroxys sp.

The larval nematodes obtained from the muscular stomach wall of *D. maculatus* did not have reproductive structures of any sort; however, the configuration of the digestive tract, the structures on the cephalic region (2 triangular lips surrounded by pseudolabiae), a poorly developed oral cavity, and the type of host make it possible to place the species in *Spiroxys* Schneider, 1866. Measurements from specimens examined here are compared to those of Moravec et al. (1995) and Osorio et al. (1987) in Table 5. While the ranges of the specimens from this study are similar to those described by Osorio et al. (1987), our specimens appear smaller than those of Moravec et al. (1995).

In Mexico, larvae of *Spiroxys* spp. have been reported from many states including Nuevo León, Morelos, Puebla, and Michoacán (Pérez-Ponce de León et al. 1996). In Lake Pátzcuaro, Michoacán, the following fishes are host to the worms: *Algansea lacustris* (Mendoza 1994), *Allophorus robustus* (Peresbarbosa et al. 1994), *Chirostoma attenuatum* (Meléndez and Rosas 1995), *Goodea atripinnis* (Mejía 1987), and *Micropterus salmoides* (Ramírez 1987). In addition, larval specimens of *Spiroxys* have been reported from Tabasco in *Cichlasoma meeki* and *C. pasioni* from the "El Chiribital" Lagoon by Osorio et al. (1987), and from fishes of the cenotes of Yucatan (*C. meeki*, *C. urophthalmus*, *Poecilia* sp., *Poecilia velifera*, and *Astyanax fasciatus*; Moravec et al. 1995).

Larvae of *Spiroxys* have not been reported from Alvarado Lagoon prior to this study. This represents the first report of the genus from that locality, and it represents a new host record in *D. maculatus*. Trujillo (1995) reported larval nematodes in the stomach and intestinal wall of *C. urophthalmus* from the same lagoonal system but was not able to identify the worms to genus. In all likelihood, they were the same as the worms reported here. The prevalence of infection for *Spiroxys* sp. reported here in *D. maculatus* (21.3%) is comparable to prevalence values reported from other fishes in other localities in southeastern Mexico: 30.0% in cichlids in Tabasco (Osorio et al. 1987) and 12.0–33.3% in various species of fishes in cenotes in Yucatan (Moravec et al. 1995). The definitive hosts for *Spiroxys* sp. are aquatic turtles, and *Trachemis scripta* is a known host for *Spiroxys* sp. in Alvarado Lagoon (Altamirano et al. 1996).

TABLE 5

Morphometric features of *Spiroxys* sp. larval stages. Minimum and maximum values are presented in mm. *n* = number of individuals.

Morphometric features	This Study (*n* = 7) min–max	Moravec et al. 1995 (*n* = 5) min–max	Osorio et al. 1987 (*n* = 9) min–max
Body length	0.625–1.770	2.050–2.170	1.520–1.810
Body wide	0.033–0.050	0.060–0.078	0.050–0.060
Buccal cavity length	0.016–0.033	—	0.013–0.019
Buccal cavity wide	0.020–0.024	—	0.014–0.020
Oesophagus length	0.133–0.325	—	0.130–0.188
Distance between anus and tail end	0.053–0.068	0.246–0.264	0.066–0.085

Camallanus sp.

The *Camallanus* nematodes collected from the intestinal mucosa of *D. maculatus* had not yet developed reproductive structures and are therefore still larvae. They may be identified as *Camallanus* sp. because the anterior end is rounded and the bucal capsule is divided into 2 rounded sclerotized structures, which are smooth. *Camallanus* sp. is distinguished from other genera and species in Camallanidae by the structure of the sclerotized plates in the bucal cavity. In *Camallanus* sp., the interior margin of the dorsal and ventral plates is smooth, whereas the plates have longitudinal grooves or spiral grooves in other genera (Chabaud 1975).

Species of *Camallanus* are parasitic in the intestine of fishes, frogs, turtles, and snakes as adults. Small aquatic crustaceans like copepods act as first intermediate hosts for larval stages (Moravec et al. 1995b, Moravec and Vargas-Vazquez 1996), and freshwater fishes serve as second intermediate hosts. At least 52 species of freshwater fishes serve as second intermediate hosts for *Camallanus* spp. in North America (Stromberg and Crites 1974), and the family Camallanidae accounts for 8% of the total number of nematode larvae recorded in Mexican fishes (Moravec 2000). Both the guppy *Poecilia reticulata*, and the Mayan cichlid, *Cichlasoma urophthalmus*, are natural paratenic hosts of camallanid nematodes (Moravec et al. 1998), as we have shown for *D. maculatus*.

Larvae of *Camallanus* spp. have been reported from a variety of fishes in a number of states in Mexico. *Astyanax mexicanus* and *Cichlasoma cyanoguttatum* serve as hosts in Nuevo Leon (Pérez-Ponce de León et al. 1996). *Ilyodon whitei* is a host in Morelos (Caspeta 1996). Osorio et al. (1987) reported *Camallanus lacustrus* Zoega, 1776 from *Cichlasoma* sp., *C. meeki*, and *Petenia splendida* in Lake El Chiribital and Lake El Horizonte in Tabasco. The specimens in our study are most similar to that reported by Iruegas (see Pérez-Ponce de León et al. 1996) but differs slightly by being smaller in body length and width, and in esophagus length. Regardless, they appear to be the same species but perhaps at a different developmental stage.

This study represents a new intermediate host record (*D. maculatus*) and a new locality record (Alvarado Lagoon) for *Camallanus* sp. larvae. Though the species cannot be determined, it is clear that the specimens reported in the present study differ from specimens reported as *Camallanus* sp. in cichlids from Tabasco by Osorio et al. (1987) in Salgado-Maldonado et al. (1997). Worm rank was low in the present study (1–3 worms/host). This may be due to possible exiting of worms through the anus brought about by the stress of host capture, a phenomenon previously reported by Van Cleave and Mueller (1934) when *Camallanus* sp. exited *Perca flavenscens* at the time of capture. Caspeta (1996) reported a similar occurrence in *Ilyodon whitei*.

In Mexico, studies involving parasites of estuarine fishes are scarce. In this study, we report new habitat, host and distributions records for 4 parasite species in the Alvarado Lagoon. *Dormitator maculatus* is an intermediate host for larval stages of *C. complanatum*, presumably a paratenic host for *Spiroxys* sp. and *Camallanus* sp. and the definitive host for adult *Neoechinorhynchus golvani*. The prevalence for the 2 most commonly occurring parasites, *C. complanatum* and *N. golvani*, was high throughout the year, and intensity of infection was generally highest at the end of the rainy season (October–November) for both species.

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